

“BIOEFFICACY OF SOME NEONICOTINOID, ORGANOPHOSPHATE AND PYRETHROID AGAINST INSECT PESTS OF SOYBEAN”

Thesis

Submitted to the

**G. B. Pant University of Agriculture and Technology
Pantnagar-263 145, (U.S.Nagar), Uttarakhand, India**



By

**AKANKSHA CHAND
(B.Sc.Ag)**

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ACKNOWLEDGEMENT

O' Almighty, I thank you for instilling in me the strength to carry on, guiding me and for helping me tread in life's path honesty and sincerely

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Lastly, I will be failing in my duty, if I do not express my sympathy for all those insects that had to suffer for the cause of science and knowledge.

Dr. Neeta Gaur
Assistant Professor

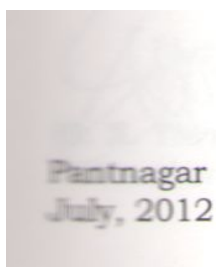


Department of Entomology,
College of Agriculture
G.B. Pant University of Agric. &
Tech., Pantnagar-263145,
U.S.Nagar, Uttarakhand, INDIA

C E R T I F I C A T E

This is to certify that the thesis entitled “**Bioefficacy of some neonicotinoid, organophosphate and pyrethroid against insect pests of soybean**” submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** with major in **ENTOMOLOGY** of the College of Post-Graduate Studies, G.B. Pant University of Agriculture and Technology, Pantnagar, is a record of *bona fide* research carried out by **Ms.AKANKSHA CHAND, Id. No. 33050**, under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been acknowledged.

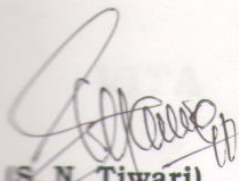



(Neeta Gaur)
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Advisory Committee

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We, the undersigned, members of the Advisory Committee of **Ms. AKANKSHA CHAND Id. No. 33050**, a candidate for the degree of **MASTER OF SCIENCE IN AGRICULTURE** with major in **ENTOMOLOGY** agree that the thesis entitled **“Bioefficacy of some neonicotinoid, organophosphate and pyrethroid against insect pests of soybean”** may be submitted in partial fulfillment of the requirements for the degree.


(Neeta Gaur)
Chairperson
Advisory Committee


(S. N. Tiwari)
Member


(Pramod Mall)
Member

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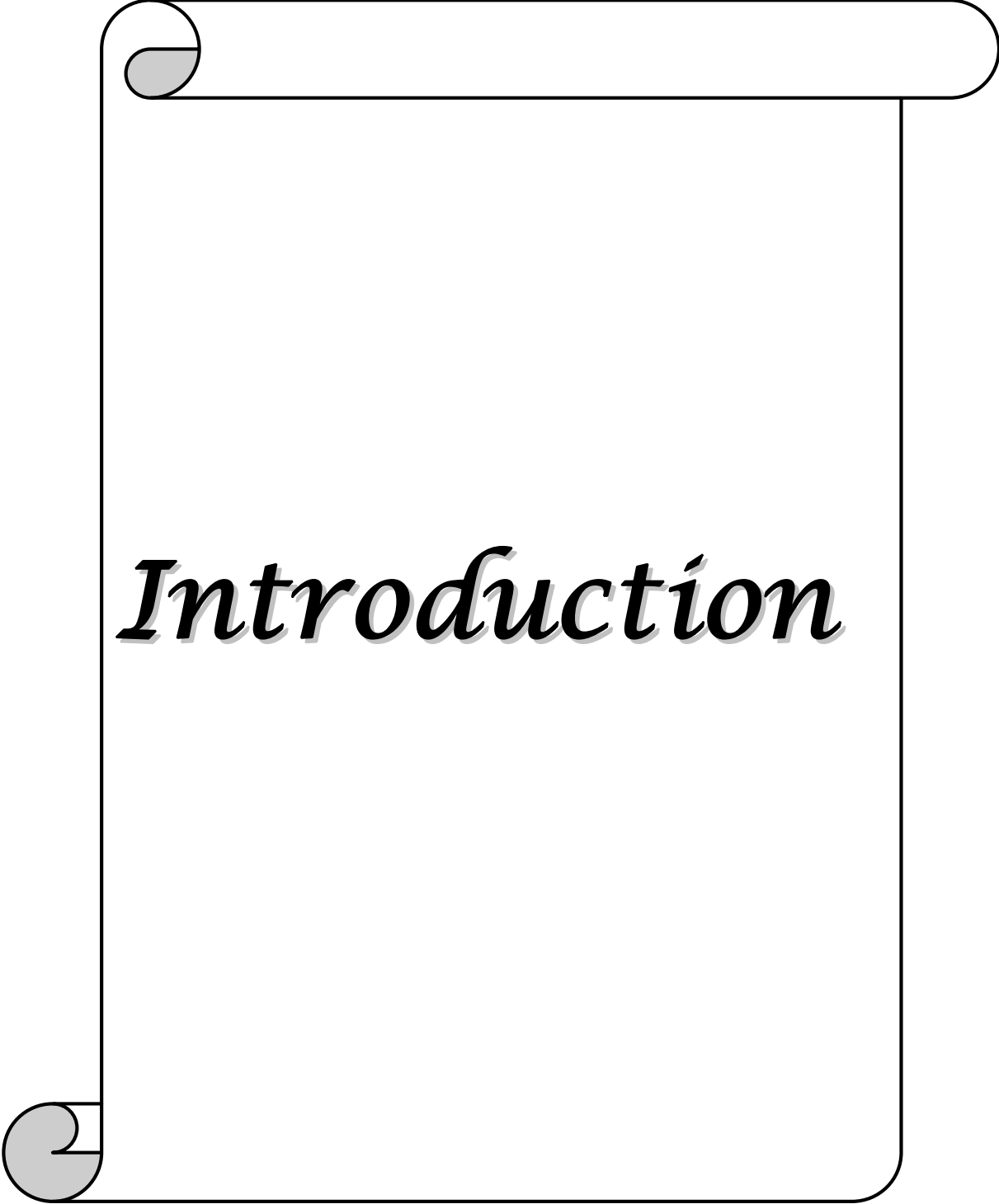
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Introduction

Soybean, *Glycine max* (L.) Merrill is a fascinating legume crop with innumerable possibilities of not only improving agriculture, but also supporting industries. Soybean is also called 'Miracle bean' because each part of the plant is used for one or the other purpose. Soybean is a major source of edible oil (20%) and high quality protein (40%) (**Deka and Talukdar, 2000**). Soybean oil is used as a raw material in manufacturing antibiotics, paints, varnishes, adhesives, lubricants etc. Soybean meal is used as protein supplement in human diet, cattle and poultry feeds. In this way it also play a vital role in providing protein nutrition. Soybean protein is rich in essential amino acids such as lysine (5%), methionine and cystine (**Murali et al., 1999**). In addition to this it also contains a good amount of minerals, salts and vitamins. By virtue of its immense nutritional potentially it is also called as "The meat of vegetarian people."

The additional advantage of this wonder crop is that, it acts as natural fertilizer. The crop builds up soil fertility by fixing large amount of atmospheric nitrogen through the root nodules containing nitrifying bacteria and also through leaf fall on the ground at maturity.

Almost all parts of soybean plant are used for various purposes especially in livestock and poultry feeds (**Singh, 1983**).

Soybean is believed to be originated in Manchuria, a South East Asian country. This crop was also known to be domesticated in Eastern China as a food crop more than 3000 years ago. Then it spread westward by Caravan to present day India and Nepal via the silk road and eastward by seagoing vessels to Japan before 6th century AD itself (**Hymowitz and Bernard, 1991**).

In India, generally crop is sown at the onset of monsoon (June-July). The black seeded variety with various local names as Bhat, Bhatmas, Ramkulthi, Kalitur etc has been grown for centuries by people in Northern hills and central part of India.

It ranks first among all the oilseed crops, based on their production in world. It is the major oilseed crop in the world accounting for about 50 per cent of total oil seed acreage as well as production. Soybean in India is cultivated over an area of 9.5 million ha with production of 11.5 million tons (**AICRP on soybean, 2010**). Whereas, in Uttarakhand, the total area, production and average yield are 900 ha, 14000 tonnes and 1556 kg/ha respectively (**Anonymous, 2009**). The estimates of world soybean area, production and yield for 2010-11 are 103.10 million ha, 257.78 million tonnes and 2.50kg/ha (**Foreign Agriculture Service, USDA**). It provides approximately 60 per cent vegetable protein and 30 per cent oil in the world. USA tops the list in soybean acreage and production. Other major soybean producing countries after USA in area and production wise are Brazil, China, Argentina, India, Indonesia, Canada, Paraguay and Italy.

World soybean production during 2011 was recorded to be 251.5 million Metric tons. Out of which United States of America with 83.2 million Metric tons ranks first (33.09%) followed by Brazil with 72.0 million Metric tons (28.64%), Argentina with 48.0 million Metric tons (19.09%) and China with 13.5 million Metric tons production (5.37%). India ranks fifth in soybean production in the World with 11.0 million Metric tons production (4.38%) (**Sharma et al., 2011**).

In oilseed and pulse scenario of India, it has now occupied first place in production next to mustard (**Anonymous, 2006**). Madhya Pradesh has the credit of being declared as the 'soybean state' amongst all the soybean growing areas of the country. The Madhya Pradesh with 5.5 m ha is the leader and is followed by Maharashtra (2.60 m ha), Rajasthan (0.69), Karnataka (0.18 m ha), AP (0.14m ha) and Chhattisgarh (0.17 m ha). At present, the total area of soybean crop in India is 93.03 lakh ha with the production of 101.29 lakh million tonnes and an average yield of 1089 kg/ha (**Anonymous, 2010**). In Uttarakhand, the total area, production and average yield are 9000 ha, 14000 tonnes and 1556 kg/ha respectively (**Anonymous, 2009**).

The low productivity of this legume crop in India is attributed to variety of limiting factors, of which insect-pest and disease are most important. During early seventies, the soybean was considered to be the safest crop as regards to insect pests attack, but with rapid increase in area under soybean, its extension to newer areas added the new insect pests which are causing great concern to its productivity.

A detailed research programme on the survey and study of the bionomics of major soybean insect pests and their management was started in Pantnagar in 1972. The study has revealed 66 species of insect belonging to six major orders, attacking soybean at different stages of crop growth (**Bhattacharya and Rathore, 1977**).

Turnipseed and Kogan (1976) has given a long list of soybean pests, of which, about two dozen consisting of stem borers, defoliators and sap suckers are considered to be the major pests of soybean in India. In *tarai* region of Uttarakhand **Shri Ram (1995)** reported that stem fly, whitefly, girdle beetle, Bihar hairy caterpillar and tobacco caterpillar are the serious pest of this crop. He also observed 33% increase in grain yield by adequate protection. Among different pests tobacco caterpillar *Spodoptera litura* (Fabricius), Bihar hairy caterpillar *Spilarctia obliqua* Walker and green semilooper *Thysanoplusia orichalcea* (Fabricius) are prevalent defoliators while among stem borers, stem fly *Melanagromyza sojae* (Zehntner) and girdle beetle *Obreopsis brevis* (Swedenbord) are more prevalent. Average losses in the soybean yield caused by insect in different state range from 18-70 per cent. (**Moscardi and Singh, 2001**). However, loss by specific insect in certain season have been recorded up to 70 per cent by *Spilarctia obliqua* (Delhi, M.P.), 80 per cent by *Helicoverpa armigera* (M.P.), 85 per cent by *O. brevis* (M.P.) and these high losses in soybean yield due to insects are extreme cases, where pest population are very high and no proper measure are being taken for their control. Hence it is needed to be plugged by insect pests management approach. Focus is also given on protection of natural enemies and human health, towards better management of insect pests for enhancing the yield of soybean crop. The indiscriminate/excessive use of the chemical insecticides had led to the development of resistance to the insecticides by the pests and created alarming situation in India (**Kranthi et al, 2002**).

To address some of the issues elaborated above, the present studies on evaluation of some insecticides against insect pests of soybean were conducted with the following objectives:

1. Efficacy of different insecticides of different groups against the major insect pest of soybean.
2. Impact of insecticides on natural enemies of soybean ecosystem.

*Review
of
Literature*

Soybean, a legume which has gained recently an important status along food crops especially pulses, and rightly said to be a ‘miracle crop’. An extensive research has been done in the field of soybean insect pest complex and their management to boost up the production of soybean. A number of insecticides have been evaluated against insect pest complex of soybean. The literatures have been reviewed under the following headings:-

- 2.1 **Insect pest complex of soybean**
- 2.2 **Biology of major insect pests and their nature and extent of damage**
- 2.3 **Control by conventional insecticides**
- 2.4 **Control by novel insecticides**
- 2.5 **Impact on natural enemies’ population**

2.1 Insect pest complex of soybean

In the recent year’s entomologist have paid great attention to study the pest complex associated with different stages of crop.

Fletcher (1922) was the earliest worker to report the incidence of nine species of insects occurring on soybean from India. **Ayyar (1963)** reported two insects of soybean crop from south India. **Singh (1968)** collected more than two dozens of insect pests associated with soybean from *tarai* and *kumaun* hills. **Tungwell et al. (1973)** collected 267 insect species from soybean field in Arkansas, USA. Approximately 380 different species of insects have been collected from soybean crop from many part of the world (**Luckmann, 1971**). **Singh (1968)** noticed 56 insects and mite pests on soybean crop from Pantnagar (Uttarakhand).

Different researchers reported 16 (**Mundhe, 1980**), 100 (**Gangrade, 1974**) and 273 (**Singh, 2001**) insect pests attacking soybean at different growth stages.

Rai et al., (1973) presented a list of 24 insect species feeding on soybean in Karnataka. **Bhardwaj and Bhalla (1976)** observed 30 insect pests belonging to six orders causing varying degree of damage to soybean in Himanchal Pradesh. **Bhattacharjee (1986)** reported numerous pests of various kinds at germination, seedling and vegetative stage of soybean in New Delhi.

General survey on the arthropod pests of soybean was initiated at Jabalpur in 1966 under the All India Co-ordinated Research Programme on Soybean. **Rawat and Kapoor (1968)** first time compiled a comprehensive report on more than 2 dozen species of arthropod pests of this crop.

Gangrade (1974) launched a research programme on the “Assessment of effects on yield and quality of soybeans caused by major arthropod pests” and observed more than 100 insect species belonging to the different orders which included Hemiptera, Lepidoptera, Coleoptera, Diptera, Orthoptera, Thysanoptera and Collembola attacking soybean. **Gangrade (1974)** also studied the biology of 15 insects in detail.

It was recorded that two species of ground beetle, *Gonocephalum drosogranulosum* Fairm and *Opatroides punctulatus* Bull. damage the cotyledons of germinating seeds from June to August.

Singh et al. (2000) reported three hundred species of insect pests infesting soybean and among them blue beetle, green semilooper and stem fly were major insect pests in Madhya Pradesh.

Patil (2002) reported that soybean was attacked by 48 phytophagous species, among these the seedling borers, *Melangromyza sojae* Zehnter, *Obereopsis brevis* Swed, leaf eating caterpillar, *Spodoptera litura* Fab and pod borer, *Cydia ptychora* Meyrick were key pests during *kharif*. Whereas, leaf miners, *Aproaerema modicella* Deventer, white fly, *Bemisia tabaci* Genn. and leaf hopper were major during summer.

Tobacco caterpillar [*Spodoptera litura* (Fab.)] is one of the most important pests of soybean (**Singh et al., 1988**). It has high reproductive capacity and ability to migrate over long distances in the adult stage. **Chari and Patel (1988)** recorded it, as an important foliage feeder on more than 112 plant species from India.

The most serious lepidopteran defoliator in Tennessee, Kentucky, and Missouri is green cloverworm (**Higley and Boethel, 1994**)

A detailed research programme on the survey and study of the bionomics of major soybean insects and their chemical control was initiated at Pantnagar in 1972. During this detailed study, 66 species of six major orders of class insecta which attack soybean during various stages of crop growth were identified (**Bhattacharya and Rathore, 1997**).

In Tarai regions of Uttarakhand, Bihar hairy caterpillar [*Spilarctia obliqua* (Walker)], Tobacco caterpillar [*S. litura* (Fab.)], Green semilooper (*T. orichalcea*), Stem fly [*M. sojae* (Zehntner)], White fly [*Bemisia tabaci* (Genn.)], Girdle beetle [*Obereopsis brevis* (Swedenborg)] etc. are serious pests of soybean crop. (**Shri Ram, 1997**)

Chaturvedi et al. (1998) reported that during *kharif* of 1995, 17 insect and one mite species were recorded infesting soybean variety JS 72-44 (Gaurav) sown on 15 July 1995. one sucked the cell sap and one damaged the roots at different growth stages of the crop, starting just after the emergence of the cotyledons.

The soybean aphid, *Aphis glycine* Matsumura, was first discovered in North America in July 2000 and has become the single most important arthropod pest of soybean in North America (**David et al., 2004**).

The most abundant phytophagous stink bug in South is southern green stink bug which occurs in Texas, Southern Arkansas, and Southeastern states (**Higley and Boethel, 1994**).

The population density of some insects associated with soybean was estimated in a field experiment in India in *kharif*, 1985. Population density of *S. obliqua* (Walk.) and *S. litura* (Fab.) were maximum around the second half of October at the maturity phase of the crop. However, densities of *T. orichalcea*, *Aphis* species, *Empoasca* species and thrips were higher during the later part of September or early October (**Kumar and Bhattacharya, 1988**).

Shri Ram (1996) reported that the major insect pests cause more than 25% reduction in yield. Population of defoliators, *Bilobu subsecivella*, *Chrysodexis acuta*,

S. litura, *S. obliqua* were low on early sown (22 June and 2 July) soybean. Incidence of these pests was high in crop sown between 12 July and 1 August (**Mandal et al., 1998**).

Kumar (1978) reported the lowest incidence (2.43%) of pod borer on soybean sown during the month of May whereas July and August sown crop had maximum incidence of 95.55% and 64.8%, respectively. In field studies carried out during 1988-89 in Orissa, the *kharif* soybean crop suffered greater damage by insect pests than *rabi* crop. Lowest pest incidence and greatest yield were recorded with early sowing during 20th June and 5th July (**Sontakke and Mishra, 1994**).

Average avoidable losses in soybean yield caused by insects in different states ranges from 18 to 70%. However losses by specific insects in certain seasons have been recorded upto 70% by *S. obliqua* (Delhi, M.P.), 80% by *Helicoverpa armigera* (M.P.) and 85% by *O. brevis* (M.P.) (**Moscardi and Singh, 2001**).

2.2. Biology of major insect pests, their extent and nature of damage

To combat the economic losses caused by the serious insect pests, it becomes mandatory to study the biology, damaging and susceptible stages and nature of damage of these major pests, in order to formulate the best management strategy for their control.

2.2.1 Leaf defoliators

Soybean is infested mainly by lepidopteran defoliators like Bihar hairy caterpillar (*S. obliqua*), Tobacco caterpillar (*S. litura*) and Green semilooper (*T. orichalcea*). These defoliators [*S. litura* (Fab.), *T. orichalcea* (Fab.), *S. obliqua* (Walk.)] and *H. armigera* (Hubner) feed on foliage, flower and pods causing significant yield.

loss (**Singh and Singh, 1990**).

2.2.1.1 Tobacco Caterpillar *S. litura* (Fabricius).

(Lepidoptera: Noctuidae)

The tobacco caterpillar, *S. litura* (Fab.) is one of the important pests of soybean (**Singh and Singh, 1988**). It has high reproductive capacity and ability to migrate

over large distance in the adult stage. The pest has its constant association with many agricultural crops causing losses to pulses, oil seeds, vegetables etc. It is an important foliage feeder, recorded on more than 112 plants species from India (**Chari and Patel, 1998**). In Punjab, it occurs sporadically mainly on cotton, castor, cauliflower, pulses, sunflower etc. (**Kumar, 1992**).

This was the first lepidopteran pest to have developed insecticide resistance in India and **Srivastava and Joshi (1965)** reported seven fold resistance towards HCH on cauliflower. Due to indiscriminate and continuous use of insecticides in cotton, *S.litura* has developed resistance against almost all group of insecticides (**Kranthi et al., 2002**).

Sanjrani et al. (1989) evaluated the effect of temperature on the biology of *S. litura* and recorded highest fecundity and fertility of eggs (1034 eggs and 100%) at average temperature of 19.55° C and lowest fecundity and fertility (387.4 eggs and 42.5%) at 34.90°C.

The adult moths of this pest are medium sized and measure 32 to 38 mm in wing span. Generally, the male moths are covered with brighter patches of light brown scales as compared to females. In contrast to female, male also possess a prominent large wide yellow oblique patch in the centre of each forewing which extends from the costal margin to the cubitus below, while most of the part of inner margin of wing is yellow. Thus, the colour pattern of the forewings serves as an important criterion on sex determination of *S. litura* (**Singh et al., 1975**).

A female moth lays up to 2100 eggs in 3 to 4 patches or clusters of 300 to 600 eggs covered with buff coloured hairs which incubate in a period of 3 to 7 days. The newly emerged larvae are green coloured with black head and having dorso-lateral black dots on the abdominal segments. The fully grown caterpillar is stout, 20-30 mm in length and become velvety in colour with row of yellow green dorso-lateral strips and lateral white bands. The larvae complete development in 20-22 days and then enter into soil for pupation. The pupae are lustrous reddish brown in colour and measure a length of 15-20 mm and width of 5 mm. The pupal period varies from 8 to 10 days. It requires 30 to 37 days to complete the development from egg to adult emergence (**Bhattacharya and Rathore, 1977**). The young larvae are of gregarious nature and

nibble the leaf from the lower surface leaving the upper surface intact. The chlorophyll of a leaf is completely consumed by the early instars of *S. litura*. Late instars larvae become distributed widely on the leaves in which they chew big holes. During severe outbreaks, they cause widespread defoliation of soybean crop (**Singh et al., 1989**).

The tobacco caterpillar, *S. litura* (Fab.) is a serious and regular pest in Madhya Pradesh. It damages soybean from mid August to October in *kharif* and from November to March in *Rabi* (**Anonymous, 2007**).

Soni et al. (2001) studied the host biology relation of *S. litura* with castor, cabbage and cauliflower in laboratory conditions. She reported that cauliflower was the most preferred host. It had shortest larval period, pre-pupal period and pupal period of 16.30, 1.15 and 10.40 days respectively but longest in castor and cabbage. It also had highest larval survival, pupation and adult emergence 94%, 85% and 92.5% respectively in cauliflower but lowest in cabbage and castor.

Bughio et al. (1994) made a quantitative study on food consumption and growth of *S. litura* on soybean which showed that younger larvae utilize food better than the older ones. Consumption and coefficient of digestibility decreased with increased larval age but efficiency of conversion of ingested and digested food to body matter increased with age.

Higher population was noticed in Dharwad and Belgaum districts of Karnataka and the pest was active during grand growth stage of the soybean (**Patil, 2002**). After damaging the leaves, they start feeding on younger parts subsequently damaging 30 to 50 per cent of the pods (**Anonymous, 2007**).

2.2.1.2 Bihar hairy caterpillar (*Spilarctia obliqua* Walker)

(Lepidoptera: Arctidae)

Bihar hairy caterpillar infesting soybean in India was first time reported by **Andrews (1915)**. It is a polyphagous pest causing damage to 124 host plants belonging to 25 families and about 25 weed species (**Purwar and Yadav, 2004**).

The Bihar hairy caterpillar, *S. obliqua* (Walk.) is a voracious feeder which feeds gregariously on soybean leaves in early instars. In case of severe infestation, the entire

crop is damaged badly causing 40% defoliation of leaf area (**Thippaiah, 1997**). **Gangrade et al. (1975)** observed 40% reduction in leaf area in soybean with larval population of 10 per meter row length.

Soybean crop is attacked by this pest during July-August and may continue up to December. Mainly caterpillars are responsible for causing damage to the plants. These are yellow to brownish in colour and their patches can easily be identified in the field. Up to third instar stage of growth, they feed gregariously on leaf-epidermis, resulting in skeletonization of the entire leaf, whereas the fully grown larvae feed solitary and consume large amount of green foliage. In severe case, these caterpillars can defoliate the entire crop (**Bhattacharya and Rathore, 1977**).

It was observed that the population of *S. obliqua* was considerably higher in plots having row spacing of 30 cm in early stage of the crop growth (30 DAS). Row spacing was not having any significant effect on the extent of defoliation (**Kumar and Bhattacharya, 1988**).

The adult moths are light yellowish brown in colour having black dots in the anterior margin of forewings. They breed from March to April and again from July to November and pass the hottest part of summer (May-June) and winter (December-February) in the pupal stage under plant debris. Adult moths emerge from the overwintering pupae in March. The moths are nocturnal and mate during night. The adult female moth lays 412-1241 spherical, light green eggs in clusters on the underside of leaves. After 12-13 days, newly emerged larvae start feeding in groups and continue up to second stage of their growth but afterwards they disperse and feed solitary. Within 4-8 weeks, they grow to maturity through 7 stages. The fully grown larva spins a silken cocoon at pupal stage which lasts for 1-2 weeks. The longevity of adult moth is about a week. The lifecycle is completed in 6-12 weeks and the pest passes through 3-4 generations in a year (**Atwal and Dhaliwal, 1999**).

Shrivastava et al. (1999) observed the foliage consumption potential of *Spilarctia obliqua* in laboratory and showed that 93.34 % of the feeding occurred in the later two instars and consumption was estimated to be 4.474 per larvae.

2.2.1.3 Green Semilooper *T. orichalcea* (Fab.) (Lepidoptera: Noctuidae)

This pest occurs in hills of Uttarakhand which include Bageshwar, Almora and Ramgarh. The pest has been previously reported damaging several crops in India (Narayanan and SubbaRao, 1955 and Singh and Rawat, 1979).

T. orichalcea (Fab) damages the crop from August to September during kharif and March to May during *rabi* season. The infestation can result into 30 per cent undeveloped pods and about 50 per cent yield loss. In case of heavy infestation, the caterpillars are also found to feed on flowers and pods (Anon., 2007).

The caterpillars are plump pale and form a characteristic half loop on walking. Adult of *T. orichalcea* are light pale brown with a large golden patch on each forewing. A single female lays up to 100 eggs, eggs are laid singly on either side of leaf in a life span of 5 days. The eggs are round in shape and hatch in 3 to 4 days. The larval period lasts from 14 to 15 days; pupal lasts from 8 to 9 days. The entire life cycle is completed in 27 to 30 days (Bhattacharya *et al.*, 1977).

Ganguli *et al.* (1989) studied migratory phase of *T. orichalcea* on the basis of reproductive development and fat body content. They showed that October- November population was considered to be immigrant with a high percentage of undeveloped ovaries, medium fat body content and unmated female. December- January is considered as local breeding period with a high percentage of developed ovaries, low fat body content and multiple mated female. For considering the nature of damage, the newly hatched larvae tend to feed on the lower surface of soybean leaves, which they scarify. The older larvae eat at the margin of the leaves leaving a jagged edge. During the heavy infestation, they denude the plants and sometimes devour flower and young pods.

2.2.2 Stem Borers

2.2.2.1 Stem Fly *M. sojae* (Zehntner)

(Diptera: Agromyzidae)

In India, it is serious stem borer of soybean in Uttarakhand, Uttar Pradesh, Delhi and Madhya Pradesh. The adult flies are approximately 2 mm long and appear to

be light brown when it emerges from the pupal case. Female are slightly bigger than males. Eggs are laid in slit made by ovipositor in the epidermis on underside of leaves. Eggs hatch in 2-7 days and larvae cause major damage by mining the leaves and form tunnel as in petiole and pass towards the central portion of stem. Pupae are barrel shaped, white and some-what dark yellowish to brown in colour, it lasts for about 7 to 10 days. Total life cycle takes 21-35 days for completion depending on climate (**Bhattacharya and Rathore, 1977**). **Adimani (1976)** observed the seasonal incidence of soybean pod borer; *Cydia ptychora* and stem fly *M. sojae*. Studies indicated that *C. ptychora* was active in soybean field from September to December with incidence ranging from 10.50 to 91.29 per cent. The crop sown during June had fewer incidences (41.51%), whereas maximum incidence of the pest was observed in the July sown crop (91.29%). Stem fly, *M. sojae* occurred throughout the year infesting 63 to 100 per cent plants in crop planted at different dates. It was very severe on the crop sown during July- August (93-100%) and less during April (63.0%).

A high infestation of *M. sojae* was recorded in all plant population levels but no marked effect of plant density on insect damage was noticed. The length of tunnel at 100 DAS was maximum in plots having 0.4 million plants per ha (**Kumar and Bhattacharya, 1988**).

Gain and Kundu (1986) studied the seasonal incidence of *M. sojae* on soybean and reported that higher incidence of agromyzid was favoured by a temperature of 24.9-25.2° C, high relative humidity and high rainfall. These weather variables were positively correlated with percentage of stem tunnelling.

Ipe and Bhati (1977) considered this to be a serious pest of soybean and found secondary and tertiary infestation more destructive than primary one. They also observed withering and premature fall of flowers due to the tunnelling of stems by the maggots.

2.3 Control by conventional insecticides

The use of conventional chemical insecticides constitutes the only presently available tool that affords consistent, economical and effective suppression of insect

outbreaks on soybean (**Turnipseed et al., 1987**). Physiologically selective insecticides are presently available only for a limited number of insect pests in the field conditions. However, even broad spectrum insecticides applied as granules, seed dressings, root zone application, stem injection and leaf axial application to avoid damage to natural enemies moving on the plant surface. Separations in time could be achieved by avoiding timing of spray to coincide with period of maximum adult activity of natural enemies and pollinators (**Jayaraj et al., 1994**).

Latha et al. (1993) observed that pre-sowing treatment with imidacloprid @ 6 g/kg seed controlled *M. sojae* throughout the cropping season. **Siddique (1995)** tested the efficacy of 8 neem based pesticides compared with Triazophos 40 EC. Triazophos 40 EC reduced the stem-tunnelling significantly in comparison to neem pesticides.

Shri Ram (1997) tested efficacy of 8 new insecticides against stem fly, compared with 3 recommended insecticides (triazophos, quinalphos and endosulfan). The stem fly infestation did not differ significantly among the treatments; however, chlorpyrifos, delphos and triazophos were found more effective against stem fly.

Siddique and Trimohan (2000) evaluated carbosulfan 3G @ 30 kg/ha., applied in furrows at the time of sowing; carbosulfan 25 DS @ 30 g/kg seed, chlorpyrifos 20EC @ 4 ml/kg seed; as seed treatment and chlorpyrifos 20 EC @ 0.04%, thiamethoxam 25 WG @ 100 g/ha. and imidacloprid 17.8 SL @ 100 ml/ha.; as foliar spray against *M. sojae* and *B. tabaci*. Seed treatment with thiamethoxam 70 WS 3 g/kg seed was very effective for two years in controlling stem fly infestation and Yellow Mosaic Virus (YMV) disease transmitted by white fly, resulting in a significant increase in yield. Earlier, no other insecticide was found so effective in controlling YMV disease to such a low level (rating 2.3 and 2.2 in 1998 and 1999, respectively; compared with 5.0 to 7.7 in other insecticidal control and untreated control).

Peter and David (1998) reported residual toxicity of 8 insecticides against first and third instar larvae of *S. litura* and reported higher efficacy of endosulfan over quinalphos and carbaryl.

Singh and Singh (2000) reported that synthetic pyrethroids viz. Decamethrin, cypermethrin and lambda cyhalothrin were most toxic whereas commonly used non-

pyrethroids like endosulphan and chlorpyriphos were promising for the successful control of *S. obliqua*.

Raj kumar and Shri Ram (2002) recorded that one or two sprays of triazophos 40 EC at 800 ml/ha were effective for controlling the defoliators including *S. litura* and *Thysanopulsia orichalcea*.

Purwar and Yadav (2003) conducted an experiment in Pantnagar, Uttarakhand, India during the *kharif* season of 2000 to study the efficacy of chemical insecticides, plant extracts, insecticides of animal origin, insect growth regulators and entomopathogenic fungi against tobacco caterpillar, *S. litura* infesting soybean cultivars PK-1029 and PK-416. Conventional synthetic insecticides namely triazophos, was the most effective against *S. litura* larvae followed by the chitin inhibitor diflubenzuron. The entomopathogenic fungi, *Beauveria bassiana* was more effective than the botanical insecticide, neem seed kernel extract and insecticides with animal origin such as cow urine and cow dung ash in suppressing the population of tobacco caterpillar. Soybean cultivar PK-1029 was more resistant than PK-416 against the pest.

Bhattacharya et al. (1996) evaluated the efficacy of different insecticides against major insect pests of soybean. Chlorpyriphos was found to show better effect on stemfly than others.

Divakar and Sujith (1999) tested the efficacy of Spark 36SC (Triazophos 35%EC and Deltamethrin 1%) against *Spodoptera litura* in laboratory and field. The mortality gained was 10, 45, 60, 47 and 100 % with 400, 500, 600, 750 and 800 mg/lit while it was 100% in field.

Shri Ram and Raj Kumar (1999) reported thiomethoxam 70WS used as seed dressing @5g/kg seed and 3g/kg seed as most effective in reducing stemfly damage and increasing yield of soybean.

Procopovici and Guran (2000) found that seed treatment of soybean with Gaucho (imidacloprid) and *Rhizobium japonicum* strains SO 70, SO 110 and FL 10 resulted in an increase in yield.

Yadav et al. (2001) found that chlorpyriphos 50EC + cypermethrin 5EC were found to be the most effective in reducing the population of larvae of *S.litura*.

Chlorpyrifos 50EC+ Cypermethrin 5EC, quinalphos 20AF and ethofenprox 10EC were highly effective against stem fly. chlorpyrifos 50EC + cypermethrin 5EC gave the maximum yield followed by quinalphos 20AF and net return of Rs. 6212/ha, Rs. 6090/ha with cost: benefit ratio of 1:4.63 and 1:7 respectively.

Avila and Gomez (2003) found seed treatment with imidacloprid @ 42, 60 and 90g/ha, fipronil @ 5g/ha and thiamethoxam @ 70g/ha provided relative grain yield significantly higher than one observed in control.

Patil and Kulkarni (2004) found thiamethoxam 70WS as a seed dress for soybean was highly effective in reducing the seedling borers, stemfly and girdle beetle infestation and increasing the seed yield.

Among the different insecticidal treatments tested in field, the treatment with profenophos 0.1% gave maximum protection when recorded up to 7 days after application with 6.5% foliage damage and showed significantly superiority in controlling larval population and thereby, reducing leaf damage and increasing the grain yield (**Hole et al., 2009**).

Of the different pesticides tested against *S.litura*, monocrotophos, quinalphos, leptophos and endosulfan at 0.05% concentration were significantly effective (**Srivastava et al., 2007**).

Several insecticide tests have been shown to reduce populations of soybean looper and velvetbean caterpillar by 90-95% (**Wier et al, 2006**). In 1980, a very dry hot year in Virginia, the use of insecticides for corn earworm and spider mites increased soybean yield by 27% (**McPherson et al., 1981**).

Hall et al. (2000) reported highest mortality of soybean looper (*Plusia includens*) with spinosad at 0.012 and 0.025 lb ai/ acre. **Knight et al. (2000)** reported good potential of indoxacarb, methoxy fenozide and spinosad against soybean looper (*Thysanoplusia orichalcea*).

Dhawan et al. (2009) conducted a trial against *Spodoptera litura* at 4 different district of Punjab and irrespective of bioassay technique applied (leaf dip or direct spray) , all the 4 populations were most susceptible to emamectin benzoate followed

by to novaluron in case of direct spray method only. He also determined that five new insecticides viz. emamectin benzoate, chlorantraniliprole, pyridalyl, nuvaluron, flubendiamide were more toxic than conventional insecticides namely endosulfan, thiodicarb, chlorpyrifos.

Loc and Sachan (1997) observed that all the concentrations of monocrotophos and endosulfan decreased the growth rate of *Spodoptera litura* over control.

Sharma et al. (1997) conducted field experiment in Madhya Pradesh to determine the effect of systemic and contact insecticide on the stem fly maggot population in soybean, to know the effect of time of application of insecticides on tunnel length at different crop growth stages. The results revealed that monocrotophos (0.036%) and fenvalerate (0.012 %) were effective in reduced maggot population. Also their application at flowering proved superior to four leaf stages, to reduce tunnel length. Thus they concluded that crop stage from one week before flowering to harvest were most susceptible whereas the crop stage up to one month old crop was least susceptible to stem fly damage as evidenced by tunnel length.

A field experiment was conducted by **Kadapatti et al. (1996)** in Karnataka wherein 10 selected insecticidal formulations (EC, dust and poison bait) were evaluated against 2nd and 4th instar larvae of *S. obliqua* on sunflower. Fenvalerate spray (0.01%) and dust (0.04%), endosulfan spray (0.07%) and dust (4.0%) were the most effective treatments against the larvae after 24, 48, 72 h and 5 days after the application. Mortality was higher in the 2nd instars than 4th instars.

An experiment was conducted under laboratory conditions to determine the lethal concentration values of three bio-rational insecticides against fourth instar larvae of *S. obliqua* by larval dip method **Singh et al. (2008)**. The study revealed that after 6h of acute exposure, lufenuron gave 50 per cent mortality at 0.08 per cent, which reduced to 0.05 per cent at 12h and 0.04 per cent at 48h after exposure. Diflubenzuron caused no mortality up to 12h after exposure, at 48h the LC50 value was 0.106 per cent, which increased to 0.125 per cent at 12h after exposure. At 12h after acute contact exposure, lufenuron was found to be more toxic than cartap hydrochloride and diflubenzuron.

2.4. Control by novel insecticides

Conventional insecticides such as chlorinated hydrocarbons, organophosphates, carbamates and pyrethroids have been found successful in controlling insect pests during past five decades, thereby minimizing the losses in agricultural yields. Unfortunately, many of these chemicals are harmful to men and beneficial organisms and cause ecological imbalance. So efforts have been made to reduce the risk of human exposure to insecticides. There is great demand for safe and more selective insecticides that spare natural enemies and non target organisms (**Reitz et al., 1999**). Accordingly, many conventional pesticides have been replaced by newer bio rational pesticides. According to **Hera (2000)**, bio rational or “low risk” insecticides are synthetic or natural compounds that effectively control insect pests, but have low toxicity to non target organisms (such as human, animals and natural enemies) and the environment.

Ostlind et al. (1979) were the first to report the insecticidal activity of avermectins. The avermectins are the group of macrocyclic lactones isolated from fermentation of soil actinomycete microorganism, a Japanese strain of *Streptomyces avermectilis* Burg. It acts as agonist for gamma amino butyric acid (GABA) gated chloride channels (**Mellin et al., 1983**)

Jansson and Dybas (1998) observed that shortly after exposure to avermectins, invertebrates stop feeding and become irreversibly paralysed. In insects and mites maximum mortality was achieved in about 4 days. Although the avermectins did not exhibit rapid knockdown effect on insects, paralysis was rapid, and feeding damage to crop was minimal because feeding ceases shortly after ingestion.

Suby et al. (2008) tested certain newer insecticides with novel modes of action along with some conventional insecticides using 'leaf dip' method against 4, 7 and 10-day old larvae of *S. litura*. Emamectin benzoate 5 per cent WSG was the most effective and abamectin 1.9 per cent EC was the least effective among the insecticides tested even though both belong to avermectin group. The LC₅₀ of emamectin benzoate against 4, 7 and 10-day old larvae were recorded as 0.22, 0.25 and 0.34 ppm, respectively. The order of relative toxicity showed that emamectin benzoate is 500 to 1200 times toxic than cypermethrin across the larval stages.

Toxicity of the bioinsecticide spinosad, the semi-synthetic insecticide spinetoram, and three IGR compounds chlorfluazuron, lufenuron and methoxyfenozide against the 2nd instar larvae of *Spodoptera littoralis* were studied. Also, the joint toxic action of spinosad or spinetoram with these IGR compounds against the 2nd instar larvae of *S. littoralis* was investigated. Spinetoram (LC₅₀=8.6 ppm) was more toxic than spinosad (LC₅₀=43.1 ppm) by approximately 5 folds, after 72 h of exposure (**Rahman et al., 2007**)

Emamectin benzoate and spinetoram are two important and promising new insecticides for the management of defoliators. The toxicity of these compounds against larvae of *Spodoptera littoralis* (Boisd.) was compared using topical application and feeding techniques. Based on the LD50 values against 4th instar larvae, emamectin benzoate proved to be better than spinetoram by 31516 fold (**Abdu-Allah et al., 2010**)

Toxicity of 12 insecticides to the 3rd instar larvae of *Spodoptera litura*, 9 insecticides to 5th instar larvae of *Spodoptera litura*, and 9 insecticides to the 4th instar larvae of *S. exiqua* were tested by topical application. The toxicity of the 12 insecticides to the 3rd instar larvae of *S. litura* was in a decreasing order as emamectin benzoate, avatar, chlorfluazuron, chlorpyrifos, phoxim, flufenoxuron, tebufenozide, profenofos, endosulfan, spinosad, alpha-cypermethrin and fiproni, while the toxicity of the 9 insecticides to the 5th instar larvae was ranked as emamectinbenzoate > chlorfenapyr > avatar > methomyl > betacypermethrin > chlorpyrifos > profenofs > phoxim > endosulfan (**Pang-YunHong et al., 2007**).

Studies on the susceptibility of third instar larvae of *Spodoptera litura* to certain novel insecticides along with conventional ones was determined by the topical application technique. The order of toxicity of different insecticides was emamectin benzoate > novaluron > pyridalyl > flubendiamide > chlorantraniliprole > chlorpyrifos > thiodicarb with relative toxicities of 390.0, 19.50, 10.54, 9.75, 8.86, 1.00 and 0.95, respectively (**Dhawan et al., 2007**).

The relative susceptibility of 3 populations of *Spodoptera litura* to certain novel insecticides along with conventional treatments was determined. Among the novel insecticides tested, indoxacarb was found be the best against the Bangalore and Guntur

populations with higher relative toxicity than cypermethrin (12.1 and 15.9), fenvalerate (10.9 and 20.6) lambda -cyhalothrin (6.1 and 26.0) and profenophos (9.2 and 20.4), respectively (**Shankarganesh *et al.*, 2007**).

The relative toxicity of six insecticides to third instar larvae of *Spilarctia obliqua* (Wlk) was studied in the laboratory condition. On the basis of LC₅₀ values (% ai), the descending order of toxicity was: emamectin benzoate 5 SG , cypermethrin 10 AF, indoxacarb 14.5 SC, endosulfan 35 EC, fenvalerate 20 EC and fenpropathrin 30 EC (**Nair *et al.*, 2007**)

Studies conducted by **Singh *et al.* (2002)**, where six day old *S. litura* larvae were dipped in different concentrations of lambda cyhalothrin (0.1, 0.05, 0.025, 0.01, 0.005 and 0.0025%) for 10 second and were provided with fresh castor leaves. Larval mortality was recorded 24 and 48 h after treatment and LC₅₀ was computed. The feeding activity of *S. litura* on lambda cyhalothrin treated leaves was evaluated using no-choice feeding test. Six day old larvae were allowed to feed on castor leaves treated with different concentrations of lambda cyhalothrin (0.8, 0.4, 0.2, 0.1, 0.05, 0.025 and 0.01ppm). Observations on the leaf area consumed were recorded. The LC₅₀ values were higher than those obtained in previous experiments, indicating a probable development of resistance in this population. In the no choice feeding test, the lowest feeding area (4.52cm²) was observed in the highest concentration of 0.8 ppm, which was statistically at par with the concentrations 0.4, 0.2, 0.1 and 0.05ppm.

Deshpande *et al.* (2010) a field experiment was conducted at oilseed Research Station, Latur during Kharif 2007 and 2008, to study the efficacy of thimethoxam 30FS (seed treatment) against early sucking pest, beneficial insects and impact on germination in sunflower. Thimethoxam 30FS @ 10ml/kg seed (3 g a.i./kg seed) was found superior against early sucking pest in sunflower crop as compared to control. Thimethoxam 30FS was found safer to natural enemies and did not exhibit any phytotoxicity even at higher doses tested suggesting that it is safe to sunflower crop.

Hannig *et al.* (2009) Chlorantraniliprole is a novel diamide insecticide, efficacious for control of lepidopteron insect pests, as well as some species in the orders Coleoptera, Diptera and Hemiptera. In their study, the speed of action of

Chlorantraniliprole was compared with that of seven commercial insecticides (methomyl, lambda-cyhalothrin and fenvalerate and faster than emamectin benzoate, indoxacarb and metaflumizone) by means of ingestion bioassays against larvae of *P. xylostella* L., *Trichoplusia ni* (Hubner), *S.exigua* (Hubner) and *H. zea* (Boddie).

The results of the studies carried out on acute toxicity of emamectin and spinosad to *S. litura* for arriving at discriminating doses for resistance monitoring revealed that the pest was highly susceptible to these insecticides. The discriminating doses were fixed at 0.40 ppm for emamectin and 125 ppm for spinosad to *S. litura*. The discriminating doses when applied to the field collected populations of Coimbatore and Madurai areas, no resistance was detected, which was confirmed by very high % mortality (Stanley *et al.*, 2006).

2.5 Impact on natural enemies' population

Soybean insect pests have very large natural enemy complex these insect pests are parasitised by many parasitoid like *Cotesia spp*, *Trichogramma spp.*, *Brachymeria spp.* and many more. There are various predators preying insect pest of soybean like *Coccinella spp.*, *Crysopa spp*, spiders etc. The use of insecticides may interfere with the activities of these natural enemies. So we should use those insecticides which are least harmful to these natural enemies. Bees are our friend and helps in pollination so care should be taken to avoid those insecticides which are harmful to bees.

Boyd and Boethel (1998) evaluated residual toxicity of selected insecticides to *Geocoris punctipes* adults, *Nabis roseipennis* adults, and *Podisus maculiventris* nymphs and adults, by exposing predators to soybean foliage (treated in the field) in petri dishes. Toxicity of chlorfenapyr residues on soybean foliage was greater than that of the standard insecticide, permethrin, and another new compound, emamectin benzoate, to all 3 predaceous species. Methyl parathion treated foliage was significantly more toxic to *G. punctipes* than were the remaining insecticides, except chlorfenapyr, 6 h after application; however, by 24 h after application, percentage mortality of *G. punctipes* declined from 100 to 11.7% following exposure to parathion-methyl

residues. Duration of chlorfenapyr residues was evident up to 72 h after application, and chlorfenapyr-treated foliage was significantly more toxic to *G. punctipes* than all other insecticides 24 to 72 h after application. Insect predators are highly mobile and spend considerable time searching for prey species on agronomic plants. Thus, insecticides with persistent foliar residues generally discriminate against predaceous species as they search for prey species or when they recolonize fields previously treated with insecticides.

Baur et al. (2003) studied the effect of new insecticides with selectivity for lepidopterous pests on important hemipteran beneficial found in Louisiana soybean agroecosystems in the laboratory and the field. The results from this study indicated that both methoxyfenozide and indoxacarb affected hemipteran predator populations less than pyrethroid, organophosphorus, or carbamate insecticides. Of the two, however, indoxacarb may affect more than methoxyfenozide.

Sechser et al. (2003) found that Enamectin benzoate was relatively safe to all stages of the tested predator species when applied as two applications at 13.5 g ai/ha 1 week apart. Thiodicarb and methomyl caused some detrimental effects to the adults of the rove beetle *Paederus alfieri* Koch and the two ladybird beetles *Scymnus* spp. and *C. undecimpunctata* L. Both carbamates were safe to the larval stages of the green lacewing *C. carnea* (Stephens) and all stages of spiders. Thiodicarb was also harmless to the adults of the minute pirate bug *Orius albidipennis* (Reut.) and the mirid bug *Campylomma verbasci* (Meyer), while methomyl caused a temporary reduction of them.

The activity of predatory population (Coccinellids and *Chrysopa*) in emanectin benzoate and spinosad plots were found to be at par with untreated check indicating non toxic to these predatory natural enemies in cotton ecosystem (**Udikeri et al., 2004**).

Kim et al. (2005) evaluated the effects of selected pesticides to the predatory mite, *Amblyseius cucumeris* (Oudemans) (Acari: Phytoseiidae), in laboratory bioassays. Pyraclofos, abamectin and emamectin to them acequinocyl, bifentazate, spirotetrameth, spinosad and thiamethoxan appeared to be promising for use in integrated pest management programs where *A. cucumeris* is the major natural enemy.

Gundannavar et al. (2006) evaluated the toxicity of Fuzon 1% (emamectin benzoate) at various concentrations (1.0, 1.6, 1.9, 2.2 or 3.0 ml/litre) to *T. chilonis*, *T. pretiosum* and *T. japonicum* under laboratory conditions. The emergence of *T. chilonis* and *T. japonicum* was greatest for the control (88.67 and 8.33%, respectively), and Fuzon at 1.0 (88.00 and 82.67%), 1.6 (84.00 and 81.33%) and 1.9 (83.33 and 79.33%) ml/litre. The insecticide remained safe to *T. pretiosum* up to 2.2 ml/litre. Fuzon at 3.0 ml/litre was slightly toxic, resulting in less adult emergence (58.67, 64.67 and 70.67%) for *T. chilonis*, *T. pretiosum* and *T. japonicum*. Cypermethrin (1.0 ml/litre) resulted in the lowest levels of emergence.

Hewa et al. (2003) found that Methoxyfenozide and indoxacarb were not toxic to *Trichogramma* spp., a common egg parasitoid of *Helicoverpa* species in Australian processing tomatoes, when applied at field rates. Imidacloprid, emamectin, and taufluvinate were toxic in some experiments; they caused >97% mortality in adults 1 h after direct application. In field trials, methoxyfenozide had no harmful effects on emergence from sprayed parasitized eggs, whereas indoxacarb had a small impact (<80%) on emergence. Thus, methoxyfenozide and indoxacarb were potentially suitable for IPM of *Helicoverpa* spp. As they didn't influence adult survival or development of immature stages of *Trichogramma* spp. These results were analogous to that of Scholz and Zalucki (2000), who found that indoxacarb against *H. armigera* on sweet corn was very safe for populations of *T. pretiosum* with only minor mortality due to residues on leaves. Spinosad was moderately disruptive to this parasitoid, with about 50% mortality of individuals exposed to leaf residues or direct spraying.

Haseeb et al. (2005) reported that when field doses of six selected insecticides were tested against the immature (pupae) and mature (adult) stages of *Diadegma semiclausum* (Hellen) and *Oomyzus sokolowskii* (Kurdjumov), parasitoids of the diamondback moth, *P. xylostella* (L.). Effects of contact toxicity (direct spraying) of the six insecticides on emergence of parasitoids were found negligible on both species except permethrin which caused 37.5% mortality. All adults of both parasitoid species died 24 hours after exposure to chlorfenapyr, emamectin benzoate and permethrin.

Muthukumar et al. (2007) to determine the efficacy of botanical pesticides and new insecticides against major insect pests and their effect on natural enemies in cauliflower. Higher mean percent reduction over the control (PROC) was recorded against aphids (78.8 and 61.6 for imidacloprid at 20 g ai/ha), 80.8 and 58.5 (thiamethoxam at 75 g ai/ha) and 77.8 and 51.8 (cartap hydrochloride at 250 g ai/ha) after the first and second spraying, respectively, during 2005/06 and 80.8 and 68.2 for imidacloprid at 20 g ai/ha, 79.8 and 61.2 (thiamethoxam at 75 g ai/ha) and 78.5 and 50.9 (cartap hydrochloride at 250 g ai/ha) after the first and second spraying, respectively, during 2006/07.

P. Chandramani et al. (2007) tested the recommended dose of spinosad, cypermethrin, imidacloprid, thiomethoxam, dimethoate, monocrotophos, endosulphan, neem oil, neem seed kernel extract (NSKE) and pungam oil for oral toxicity against Indian honey bee [*A. cerana indica* (F.)] under laboratory conditions. The oral toxicity studies revealed that the toxicity of insecticides, neonicotinoid compounds and selective botanicals to *Apis cerana indica* increased with time. The descending order of oral toxicities of 10 test insecticides is cypermethrin> monocrotophos> endosulphan> dimethoate> thiomethoxam> imidacloprid> spinosad> pungam oil> neem oil and NSKE.

Chukwudebe et al. (1997) studied the persistence and residual contact toxicity of foliar dislodgeable emamectin benzoate residues to *A. mellifera* and *Diglyphus isaea* following applications to foliage at the maximum anticipated labelled use rate (0.0168 kg a.i./ha). Bee mortality from contact exposure to dislodgeable alfalfa [lucerne] residues aged for 3, 8, and 24 h was 100, 46, and 3%, respectively. This contact toxicity was directly correlated with the magnitude of dislodgeable residues (9.1, 3.6, and 1.3 ng/cm², respectively), and with a dissipation half life of about 10 h. Similarly, *D. isaea* mortality from contact exposure to dislodgeable residues aged for 0.5, 1.0, 3.5, 35, and 60 h was 75, 65, 50, 20, and 15%, respectively. These residues (5.2, 5.0, 4.5, 1.4, and <0.2 ng/cm², respectively) had a dissipation half life of about 15 h. It was concluded that these beneficial insects are expected to survive and colonize treated crops within relatively short intervals (24 h) after applications of emamectin benzoate.

Shimoda *et al.* (2011) investigated the effects of the following eight insecticides on the flight response of female parasitoids (*Cotesia vestalis*) to *Brassica rapa* infested with the larvae of their host, the diamond-back moth (*Plutella xylostella*). We found that odors from etofenprox, methomyl, and malathion strongly affect the parasitoid's foraging behavior via HIPVs, while permethrin, emamectin benzoate, and clothianidin do not. Alanycarb and diazinon are intermediate between them. We then investigated, using host-infested plants treated with diazinon or distilled water, how long the insecticide affected their flight response. At 1 and 24 h after spraying, *C. vestalis* females preferred infested, water-treated plants to infested, diazinon-treated plants. However, at 72 h after spraying, they did not discriminate between these plants, suggesting that the inhibitory effect disappears at least 72 h after spraying.

*Materials
and
Methods*

The details of materials used and methods adopted during the course of investigation are described as under:

3.1 Experimental Site

The field trials were conducted during the *kharif* season of 2011 at Norman E. Borlaug Crop Research Centre at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, India, to study the comparative efficacy of some insecticides against insect pests of soybean. Soybean crop was raised as per recommended agronomical practices. Similar cultural practices were followed in all the experimental plots, in addition specific treatments were given to various experimental plots as per treatment plan.

3.2 Climate and weather conditions

Pantnagar is situated at the foot-hills of North Western Himalayas at an altitude of 243.83 meters above the mean sea level (MSL), 29° North latitude and 79.3° East longitude. The climate is humid sub-tropical with maximum temperature ranging from 32°C to 45°C during summer and minimum ranging from 0°C to 9°C during winter. Monsoon occurs from 3rd week of June to middle of September with average annual rainfall measuring 1400 mm. (Kumar, 2000 and Dubey, 2005)

3.3 Soil characteristics

The soil of *tarai* region are developed from calcareous alluvium medium to moderately coarse textured materials under predominant influence of tall vegetation and moderate to well drained condition. The soil of experimental field was silty clay loam (series II) with weak to fine medium granular structure classified as Mollisol.

3.4 Field experiment

3.4.1 Details of field experiment

Variety	Soybean P.K.416
Row spacing	45cm
Plant spacing	5cm
Experiment design	RBD
No. of replications	3
No. of treatments	8
Plot size	25sqm (4.50m × 5.56m)
No. of rows	10
Mode of application	spraying by knapsack sprayer

3.4.2 Treatments and their allocation

Eight treatments including control were allocated randomly to different plots in each of the 3 blocks. The layout of the experiment showing the treatments allocation is given in fig.1.

3.5 Preparatory Tillage

In the experimental field, two summer ploughings were done with a disc harrow followed by cross harrowing. After monsoon, the field was ploughed twice, cross-harrowed and leveled to ensure uniform irrigation and proper drainage.

3.6 Sowing and agronomical practices

Variety PK- 416 was sown in furrows opened to a depth of 4-5 cm by hand liner. Row to row distance of 45 cm was maintained. Seeds were treated with Thiram 75% at the rate of 3.0 g/kg of seed and then inoculated with bacterial culture at the rate of 500g/75 kg seed. Fertilizers were applied to the experimental field as per the requirement and recommended dose of soybean crop in Pantnagar locality. Thinning was done 7 days after germination to maintain the plant population at desired spacing. About 0.4 million plants/ha were maintained.

Table 3.1: Weekly Weather Data for crop period (Kharif 2011)

Week N0.	Month	Dates with duration	Rainfall (mm)	Temperature (°C)		Relative humidity (%)		Sun Shine (hrs/day)	Evap (mm)	Wind velocity (Km/hr)
				Max	Min.	Max.	Min.			
23	June	04-10	016.8	36.1	23.3	75	52	10.0	7.2	7.2
24		11-17	026.8	32.9	23.8	77	60	07.8	5.5	5.9
25		18-24	060.0	34.1	25.6	82	61	05.8	5.3	6.3
26		25-01	241.0	32.1	24.9	90	78	02.0	5.0	6.2
27	July	02-08	002.6	33.0	26.1	86	70	05.3	4.0	7.4
28		09-15	237.2	33.5	25.5	89	64	05.3	3.7	6.4
29		16-22	123.2	30.9	24.6	88	72	03.5	3.2	5.9
30		23-29	195.0	31.7	25.5	89	77	03.6	4.0	5.4
31	Aug	30-05	178.4	31.9	25.5	91	70	03.0	3.6	4.2
32		06-12	085.4	32.7	25.8	87	71	05.1	4.7	7.0
33		13-19	458.0	29.2	24.5	93	85	02.6	5.3	9.5
34		20-26	111.8	31.7	24.9	91	70	06.9	4.3	4.2
35	Sep	27-02	000.0	34.4	25.9	83	62	08.3	3.8	3.0
36		03-09	164.2	32.6	24.7	87	74	06.0	5.0	5.0
37		10-16	102.4	32.5	24.4	91	68	05.8	4.0	4.0
38		17-23	001.2	31.6	23.2	91	66	07.5	3.2	3.5
39	Oct	24-30	003.8	31.5	22.2	92	67	06.7	3.0	3.4
40		01-07	0	31.6	21.4	93	63	6.1	2.7	3.4
41		08-14	0	33.3	19.4	90	57	8.2	3.1	1.7
42		15-21	0	31.6	15.9	90	56	8.5	3.1	1.7
43		22-28	0	30.9	14	89	48	8.1	2.9	2.2

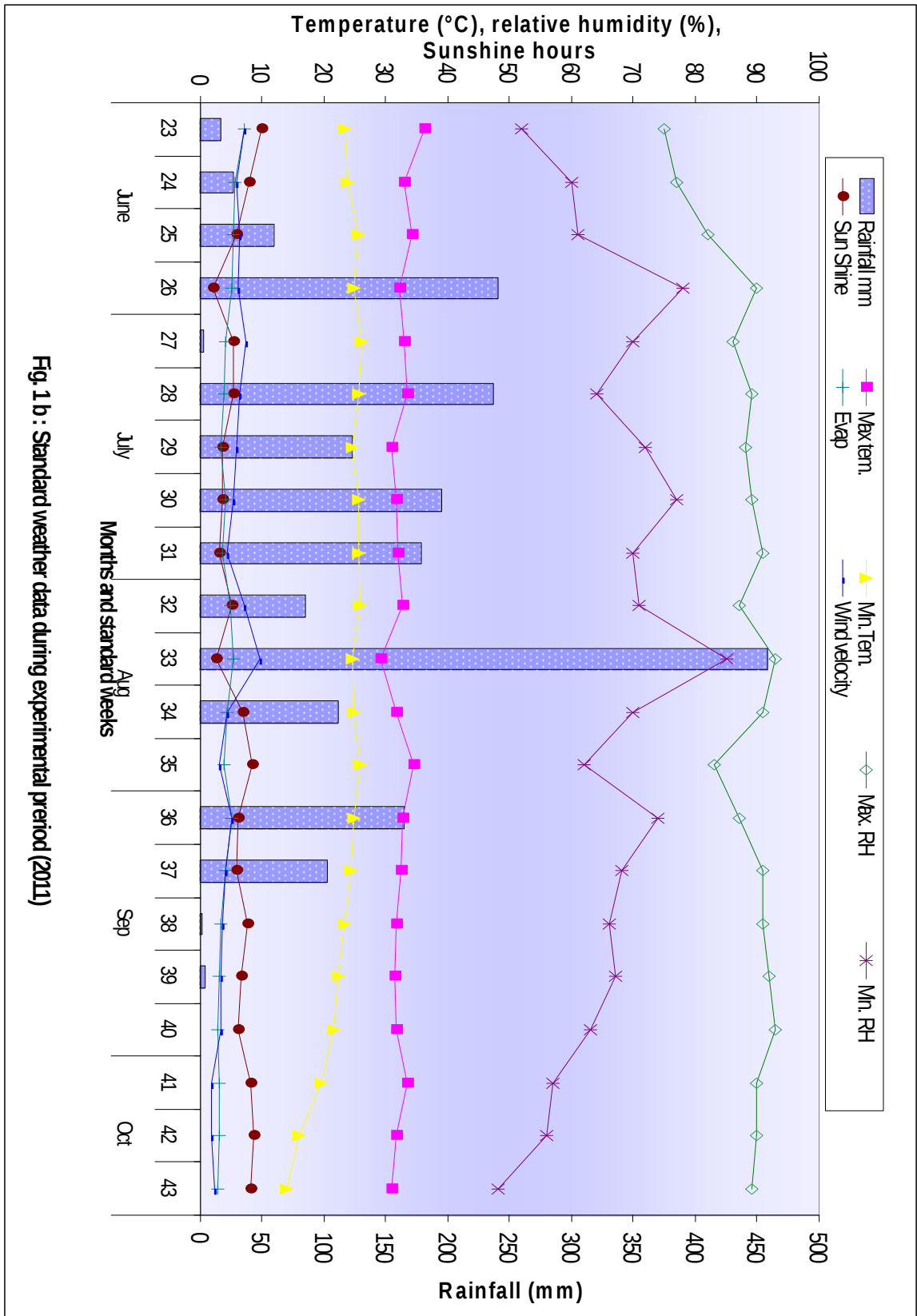


Fig. 1 b : Standard weather data during experimental period (2011)

3.7 Harvesting, threshing and recording Yield

Harvesting of the crop was done in 2nd week of November, 2011 when it was matured (leaves were dropped from plants and colour of pods turned yellow). The harvesting of all plots was done by cutting the plants close to the ground surface with the help of sickle. The borders (1 rows of each corner of plot and 0.5 m from two ends of each row) were left for harvesting. After sun drying for 6-7 days, the crop was threshed manually with sticks and grains were sun dried to bring uniform moisture. Yield was recorded from eight inner row of net cropped area ($5 \times .45 \times 8 = 18 \text{ m}^2$) by discarding one row on either side and 0.5m at both ends of row are not included.

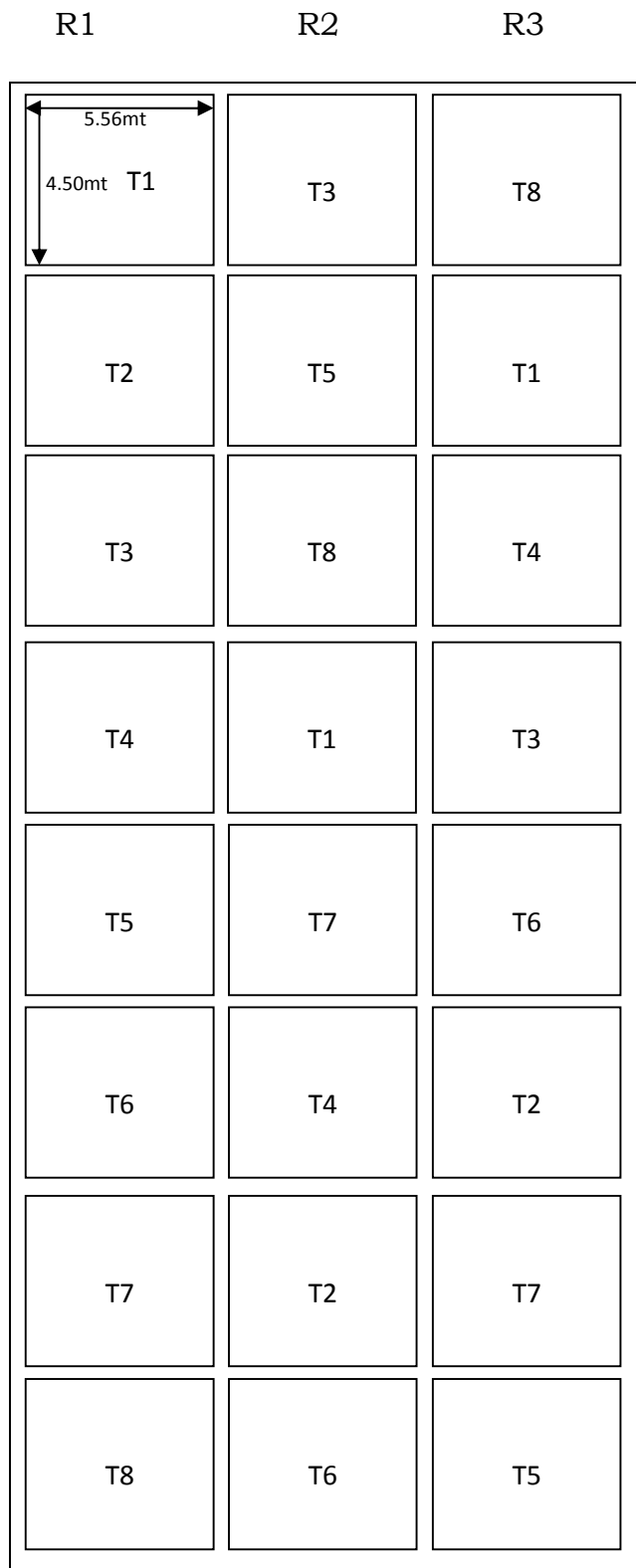
3.8 Preparation of pesticide solution

The insecticide solutions of required concentration were prepared with water and sprayed after proper stirring. The knapsack sprayer fitted with hollow cone nozzle was used to spray the solution.

Table 3.1: Details of treatments used:

S. No.	Treatment detail	Dose(ga.i./ha)
1	Thiamethoxam12.6+ Lambdacyhalothrin 9.5%ZC (Alika 247ZC)	22
2	Thiamethoxam12.6+ Lambdacyhalothrin 9.5%ZC (Alika 247ZC)	27.5
3	Thiamethoxam12.6+ Lambdacyhalothrin 9.5%ZC (Alika 247ZC)	33
4	Thiamethoxam 25% WG	25
5	Lambdacyhalothrin 49%CS	15
6	Ethion 50%EC	750
7	Imidachloprid17.8%SL	20
8	Untreated	

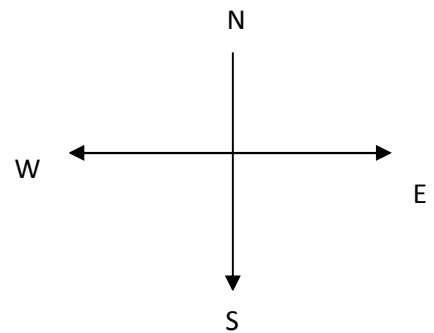
Fig: 1: The layout of the experiment showing the treatments allocation



Treatment : 8
 Replication: 3
 Design : RBD
 Plot Size : 4.5mx5.56m

(25msq)

Total plots: 32



3.9 Observation procedure

The observations were recorded 1 day before (DBS), and 1,3,7 and 10 days after spraying (DAS). For obtaining correct information on insect populations, standard sampling techniques were followed as described by Bhattacharya and Rathore (1977).

3.9.1 Observation of Lepidopterous Larval Population : The plant shaking method was employed for estimating the population of lepidopterous larvae. Rectangular transparent polythene sheet (50cm×60cm) was used for this purpose. The observations were taken on 1 day before (DBS) and 1, 3, 7 and days after sowing (DAS).

3.9.2 Observation of Stem fly tunneling and plant infestation : It was recorded at the time of harvesting by dissecting 10 plants per plot. The yield of soybean was also recorded separately as per treatment.

3.9.3 Observation on grain yield

All the plants from the net area obtained by leaving the border row of each plot and 0.5m from row of each side of plots were harvested at maturity. After performing post-harvest operations, the grains were taken and filled in cloth bags. The bags were kept at ambient temperature for one week for stabilization of the normal moisture content of grain. Then the yield per hectare for each treatment was computed.

3.10 Statistical analysis

The computation of analysis of variance of data collected from field experiment were done by using Randomized Block Design (RBD).

Per cent data was transformed to angular transformation, while the data regarding different insect population was subjected to square root transformation. After determination of significance of difference between the treatment means at (0.05) percent probability, critical difference was calculated in order to compare the treatment means. Valid conclusions were drawn by using F-test.

*Results
and
Discussion*

Insects pests recorded during *Kharif*-2011 on soybean at Pantnagar, Uttarakhand, included mainly various types of defoliators, sap suckers and stem borers. Insect population includes defoliators viz. tobacco caterpillar, green semilooper, Bihar hairy caterpillar; stem borers i.e. stem fly and natural enemies i.e. spider, Coccinella, *Canthoconid* bug.

The effect of various treatments on pest population during *kharif*-2011 is being discussed below.

4.1 Defoliators

4.1.1 Tobacco caterpillar, *Spodoptera litura* (Fab.)

The data on larval population in term of number of larvae per meter row length (mrl) of *S. litura* in various treatments during *kharif* 2011 was recorded one day before and 1, 3, 7 and 10 days after each application. The results of first spray are summarized in Tables 4.1.

The incidence of *S. litura* was recorded on 98 days after sowing i.e. 1 day before first spray, it varied from 1 to 7 larvae/meter row length (mrl).

After 1 day of spray in all treatments there was reduction in population of *S.litura*. Highest mean number of larvae was found in Imidacloprid 17.8%SL @20g ai/ha i.e. 4.33 larvae/mrl and control plot 6.33 larvae/mrl. One day after spray there was a 100% reduction in Alika 247ZC @ 33g ai/ha.

After three days of spraying, all the test chemicals demonstrated better performance against tobacco caterpillar except Alika247zc @ 22g ai/ha i.e. larval count increased from 3.66 to 5.00 larvae/mrl. There was a 100% reduction in case of Alika 247ZC @ 33g ai/ha. The mean number of larvae in Alika247zc @ 22g ai/ha, Alika247zc @27.5g ai/ha, Thiamethoxam 25%wg @25g ai/ha, Lambdacyhalothrin 4.9% @ 15g ai/ha, Ethion 50%EC @750g ai/ha and Imidacloprid17.8%SL @20g ai/ha

were 5.00, 1.33, 3.33, 2.33, 2.66 and 3.33 respectively. The mean number of occurrence of larvae/mrl was highest in untreated control plot i.e. 5.66larvae/mrl.

After 7 days the lowest mean number of larvae was found in of Alika 247ZC @ 33g ai/ha and highest was in untreated.

Ten days after spraying, the larval population varied from 0 larvae/mrl (with Alika247zc @ 33g ai/ha and Alika247zc @27.5g ai/ha) to 5.00 larvae/mrl with control.

Based on percent mortality at 10 DAS, the treatment can be put in descending order as Alika247zc @ 33g ai/ha > Alika247zc @27.5g ai/ha > Thiamethoxam 25%wg @25g ai/ha> Imidacloprid17.8%SL @20g ai/ha > Lambdacyhalothrin 4.9% @ 15g ai/ha > Ethion 50%EC @750g ai/ha > Alika247zc @ 22g ai/ha.

The results of second spray on observation of larval population one day before and 1, 3, 7 and 10 days after spray are summarized in Tables 4.2.

Observation of larval population 1 day before was taken on 110 DAS and there was a variability in the mean number of larvae/mrl, the lowest mean was 1.33 and the highest was 6.00.

One day after spray Alika247zc @ 33g ai/ha provided 100% control followed by Alika247zc @27.5g ai/ha which was followed by Alika247zc @ 22g ai/ha, Thiamethoxam 25%wg @25g ai/ha, Ethion 50%EC @750g ai/ha, Imidacloprid 17.8%SL @20g ai/ha all are at par with each other. The lowest control was recorded in Lambdacyhalothrin 4.9% @ 15g ai/ha and untreated plot.

Three days after spray, the larval population in Alika247zc @ 33g ai/ha was 0.00 followed by Alika247zc @27.5g ai/ha having 0.33 larvae/mrl. Ethion 50%EC @750g ai/ha and Lambdacyhalothrin 4.9% @ 15g ai/ha have 2.00 and 1.66 larvae/mrl respectively. Highest larval population was found in control followed by Alika247zc @ 22g ai/ha.

Seven day after spray the larval count was lowest in Alika247zc @ 33g ai/ha followed by Alika247zc @27.5g ai/ha., Ethion 50%EC @750g ai/ha, Imidacloprid 17.8%SL @20g ai/ha and Lambdacyhalothrin 4.9% @ 15g ai/ha all three have same larval count i.e. 1.33larvae/mrl. Alika247zc @ 22g ai/ha was having 3.33 larvae/mrl.

Table 4.1: Effect of different treatments on *Spodoptera litura* infestation in soybean crop during *kharif*, 2011 (1st spray)

Treatments	Number of larvae/meter row length					
	1DBS	1DAS	3DAS	7DAS	10DAS	MEAN
Alika247zc @ 22g ai/ha	4.66 (2.27)	3.66 (2.03)	5.00 (2.33)	4.00 (2.11)	3.00 (1.67)	4.06 (2.08)
Alika247zc @27.5g ai/ha	2.66 (1.76)	1.33 (1.34)	1.33 (1.28)	0.66 (1.05)	0.00 (0.87)	1.19 (1.26)
Alika247zc @ 33g ai/ha	1.00 (1.22)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.20 (0.80)
Thiamethoxam 25%wg @25g ai/ha	4.66 (2.27)	4.00 (2.11)	3.33 (1.95)	2.66 (1.77)	1.00 (1.46)	3.13 (1.92)
Lambdacyhalothrin 4.9% @ 15g ai/ha	4.66 (2.26)	4.00 (2.11)	2.33 (1.67)	1.66 (1.46)	1.00 (1.22)	2.73 (1.73)
Ethion 50%EC @750g ai/ha	5.00 (2.33)	4.00 (2.11)	2.66 (1.76)	2.00 (1.55)	2.00 (1.34)	3.13 (1.81)
Imidacloprid17.8%SL @20g ai/ha	5.33 (2.41)	4.33 (2.19)	3.33 (1.95)	2.33 (1.67)	1.00 (1.34)	3.26 (1.91)
Untreated	7.00 (2.73)	6.33 (2.61)	5.66 (2.47)	4.66 (2.26)	5.00 (2.11)	5.73 (2.43)
SEm ±	0.4650 (0.1075)	0.4520 (.1106)	0.4607 (.1361)	.4249 (.1268)	.3478 (.1182)	
Cd at 5%	1.410 (.3261)	1.371 (.3355)	1.397 (.4130)	1.28 (.3846)	1.055 (.3586)	

Data in Parenthesis indicate square root transformation value $\sqrt{x+0.5}$

DBS =Days Before Spraying

DAS = Days After Spraying

Table 4.2: Effect of different treatments on *Spodoptera litura* infestation in soybean crop during *kharif*, 2011 (2nd spray)

Treatments	Number of larvae/meter row length(mrl)					
	1DBS	1DAS	3DAS	7DAS	10DAS	MEAN
Alika247zc @ 22g ai/ha	3.66 (2.03)	2.33 (1.67)	4.00 (2.11)	3.33 (1.95)	2.00 (1.58)	3.06 (1.86)
Alika247zc @27.5g ai/ha	2.00 (1.55)	0.66 (1.05)	0.33 (0.87)	0.33 (0.87)	0.33 (0.87)	0.73 (1.04)
Alika247zc @ 33g ai/ha	1.33 (1.34)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.26 (0.82)
Thiamethoxam 25%wg @25g ai/ha	2.33 (1.67)	2.33 (1.67)	2.66 (1.77)	1.66 (1.46)	1.00 (1.22)	1.99 (1.55)
Lambdacyhalothrin 4.9% @ 15g ai/ha	3.00 (1.85)	2.66 (1.77)	1.66 (1.46)	1.33 (1.34)	0.66 (1.05)	1.86 (1.49)
Ethion 50%EC @750g ai/ha	3.66 (2.03)	2.33 (1.67)	2.00 (1.55)	1.33 (1.34)	0.66 (1.05)	1.99 (1.52)
Imidacloprid17.8%SL @20g ai/ha	3.66 (2.02)	2.33 (1.67)	2.00 (1.58)	1.33 (1.34)	1.00 (1.22)	2.06 (1.56)
Untreated	6.00 (2.48)	4.66 (2.27)	5.33 (2.41)	3.66 (2.02)	3.00 (1.85)	4.53 (2.20)
SEm ±	0.4564 (.118)	.3212 (.1057)	.3421 (.1087)	.3753 (.1238)	.2852 (.1166)	
Cd at 5%	1.384 (.3586)	.9741 (.3206)	1.037 (.3298)	1.138 (.3754)	.8650 (.3536)	

Data in Parenthesis indicate square root transformation value $\sqrt{x+0.5}$

DBS =Days Before Spraying

DAS = Days After Spraying

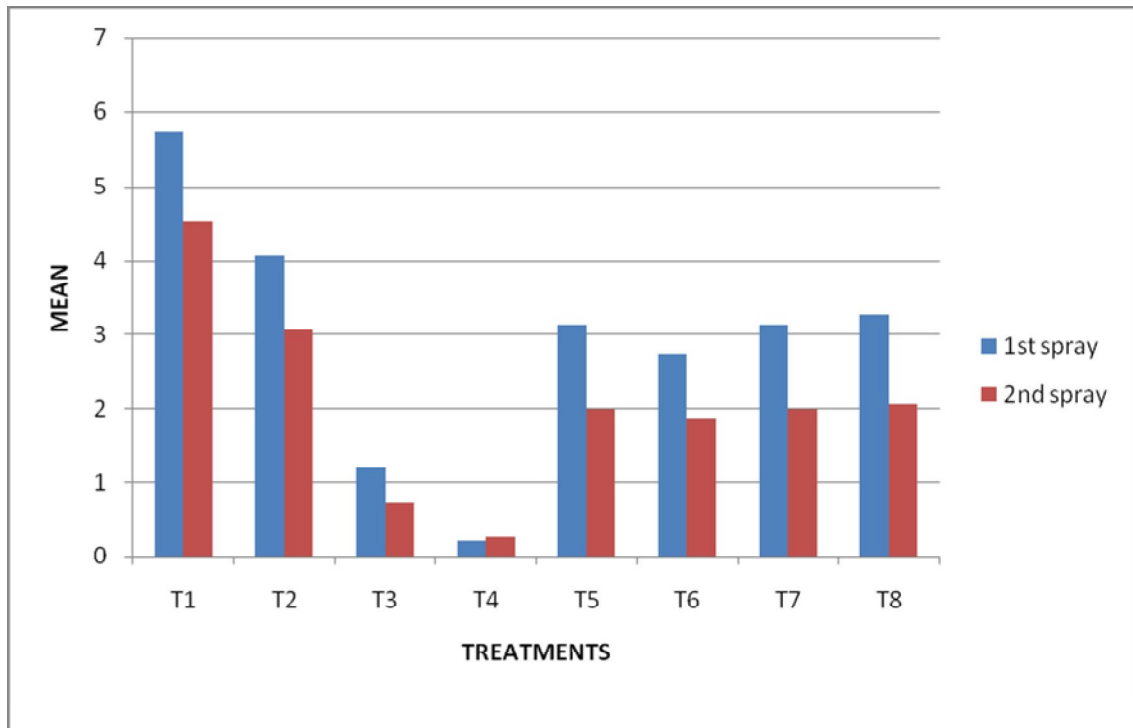


Fig. 2: Effects of different treatments on *Spodoptera litura* infestation in soybean crop during Kharif, 2011

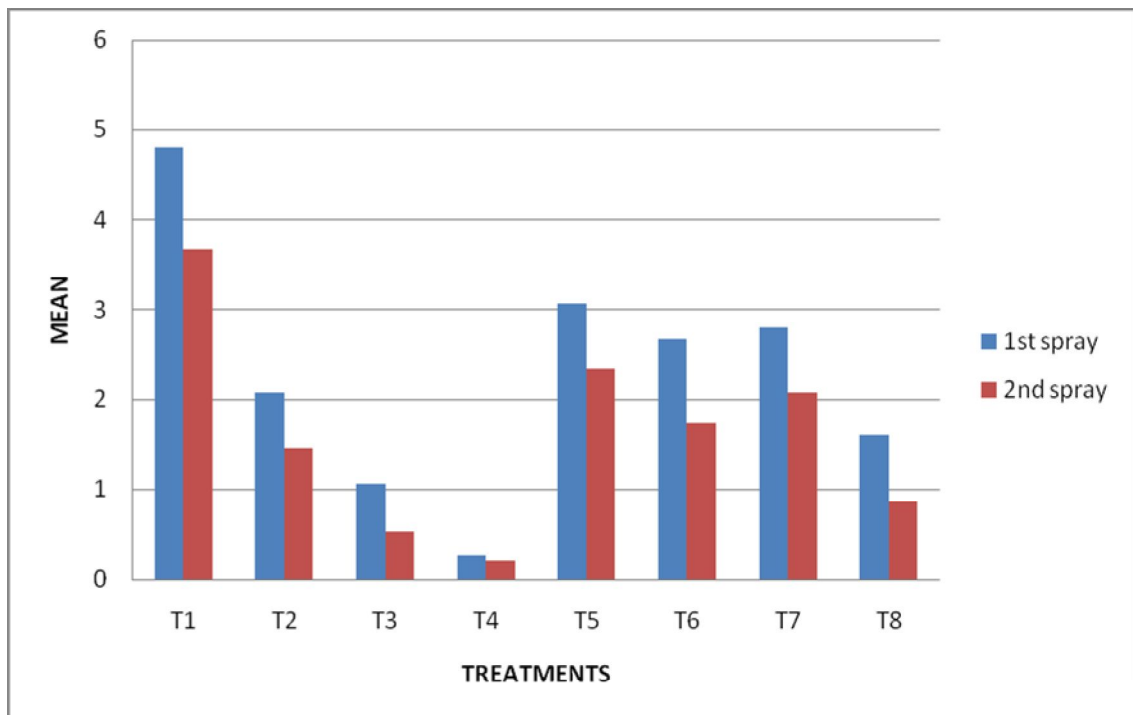


Fig. 3: Effect of different treatments on *Thysanopplusia orichalcea* infestation in soybean crop during Kharif, 2011

Ten days after spray the larval population was less than the 7th day of spray except Alika247zc @ 33g ai/ha i.e. 0.00 and Alika247zc @27.5g ai/ha i.e.0.33. All the treatments demonstrated a significant reduction in mean larval population. The lowest reduction in larval population was in Alika247zc @ 22g ai/ha and untreated plot.

On the basis of overall mean Alika247zc @ 33g ai/ha and Alika247zc @27.5g ai/ha were found more effective against *S.litura* among all other insecticides.

On overall basis of both spray Alika247zc @ 33g ai/ha gave the best control of *S.litura* and Ethion 50%EC @750g ai/ha, Imidacloprid17.8%SL @20g ai/ha and Lambdacyhalothrin 4.9% @ 15g ai/ha gave satisfactory results but Alika247zc @ 22g ai/ha was not much effective for control of *S.litura*.

4.1.2 Green semilooper, *Thysanoplusia orichalcea* (Fab.)

Observation of larval population after first spray was taken 1day before and 1, 3, 7 and 10 days after spray and the results are summerised in table 4.3.

The population of *T. orichalcea* before first spray ranged from 1.33 to 6.66 larvae/mrl.

One day after spray there was cent percent control with Alika247zc @ 33g ai/ha. The highest larval population was found in control (6.00) followed by Thiamethoxam 25%wg @25g ai/ha (4.66) and Lambdacyhalothrin 4.9% @ 15g ai/ha (4.66).

Three day after spray on basis of percent mortality the treatment can be put in decending order as Alika247zc @ 33g ai/ha > Imidacloprid17.8%SL @20g ai/ha > Alika247zc @27.5g ai/ha > Alika247zc @ 22g ai/ha > Thiamethoxam 25%wg @25g ai/ha, > Ethion 50%EC @750g ai/ha > Lambdacyhalothrin 4.9% @ 15g ai/ha > control.

Seven days after spray the larval population was 0.00, 0.66, 1.00, 1.66, 1.66, 2.00 and 2.33 in Alika247zc @ 33g ai/ha , Alika247zc @27.5g ai/ha, Imidacloprid 17.8%SL @20g ai/ha, Alika247zc @ 22g ai/ha, Lambdacyhalothrin 4.9% @ 15g ai/ha, Thiamethoxam 25%wg @25g ai/ha, Ethion 50%EC @750g ai/ha respectively.

Ten days after spray there was 100% control with Alika247zc @ 33g ai/ha. Larval population was 0.33 larvae/mrl in Alika247zc @27.5g ai/ha and Imidacloprid 17.8%SL @20g ai/ha. It was 1.00 larvae/mrl in Lambdacyhalothrin 4.9% @ 15g ai/ha and it was 1.33 larvae/mrl in Alika247zc @ 22g ai/ha, Thiamethoxam 25%wg @25g ai/ha and Ethion 50%EC @750g ai/ha.

On the basis of overall mean the treatments can be put in decending order according to their effectiveness as Alika247zc @ 33g ai/ha > Alika247zc @27.5g ai/ha>Imidacloprid17.8%SL @20g ai/ha > Alika247zc @ 22g ai/ha > Lambdacyhalothrin 4.9% @ 15g ai/ha > Ethion 50%EC @750g ai/ha >Thiamethoxam 25%wg @25g ai/ha >untreated.

The results of second spray are summerised in table 4.4. The incidence of *T. orichalcea* varies from 1 to 4.33 larvae/mrl which was recorded on 110 days after sowing i.e. 1 day before 2nd spray.

On one day after spray Alika247zc @ 33g ai/ha was found to be most effective giving 100% control followed by Alika247zc @27.5g ai/ha. Imidacloprid17.8%SL @20g ai/ha and Alika247zc @ 22g ai/ha gave equal results with 1.33 larvae/mrl. Highest larval population was found in untreated plot with 5.00 larvae/mrl followed by Thiamethoxam 25%wg @25g ai/ha with 3.33 larvae/mrl.

Three day after spray Alika247zc @ 33g ai/ha had lowest larval population, i.e. 0.00. The mean number of larvae in Imidacloprid17.8%SL @20g ai/ha, Alika247zc @27.5g ai/ha, Alika247zc @ 22g ai/ha, Thiamethoxam 25%wg @25g ai/ha, Ethion 50%EC @750g ai/ha, Lambdacyhalothrin 4.9% @ 15g ai/ha were 0.66, 0.66, 1.66, 1.66, 2.00, 2.00 respectively.

Seven day after spray highest larval population was found in control followed by Thiamethoxam 25%wg @25g ai/ha. Imidacloprid17.8%SL @20g ai/ha, Alika247zc @27.5g ai/ha gave at par results with larval population of 1.33 larvae/mrl. Alika247zc @ 33g ai/ha gave cent percent control.

Ten day after spray Alika247zc @ 33g ai/ha, Imidacloprid17.8%SL @20g ai/ha and Alika247zc @27.5gai/ha give 100% control followed by Alika247zc @ 22g ai/ha

Table 4.3: Effect of different treatments on *Thysanopplusia orichalcea* infestation in soybean crop during *kharif*, 2011 (1st spray)

Treatments	Number of larvae/meter row length					
	1DBS	1DAS	3DAS	7DAS	10DAS	MEAN
Alika247zc @ 22g ai/ha	2.33 (1.67)	2.66 (1.76)	2.33 (1.67)	1.66 (1.46)	1.33 (1.34)	2.06 (1.58)
Alika247zc @27.5g ai/ha	2.00 (1.58)	0.66 (1.05)	1.66 (1.46)	0.66 (1.05)	0.33 (0.87)	1.06 (1.20)
Alika247zc @ 33g ai/ha	1.33 (1.34)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.26 (0.82)
Thiamethoxam 25%wg @25g ai/ha	4.66 (2.27)	4.66 (2.25)	2.66 (1.73)	2.00 (1.55)	1.33 (1.34)	3.06 (1.82)
Lambdacyhalothrin 4.9% @ 15g ai/ha	3.00 (1.85)	4.66 (2.11)	3.00 (1.85)	1.66 (1.46)	1.00 (1.22)	2.66 (1.69)
Ethion 50%EC @750g ai/ha	4.00 (2.11)	3.66 (2.03)	2.66 (1.77)	2.33 (1.67)	1.33 (1.34)	2.79 (1.78)
Imidacloprid17.8%SL @20g ai/ha	3.00 (1.85)	2.33 (1.67)	1.33 (1.34)	1.00 (1.22)	0.33 (0.87)	1.59 (1.39)
Untreated	6.66 (2.67)	6.00 (2.54)	5.33 (2.40)	3.66 (2.03)	2.33 (1.67)	4.79 (2.26)
SEm ±	.4249 (.0646)	.3212 (.8225)	.3450 (.9701)	.2920 (.1076)	.2988 (.1225)	
Cd at 5%	1.288 (.1960)	.9741 (.2494)	1.046 (.2942)	.8858 (.3264)	.9062 (.3717)	

Data in Parenthesis indicate square root transformation value $\sqrt{x+0.5}$

DBS =Days Before Spraying

DAS = Days After Spraying

Table 4.4: Effect of different treatments on *Thysanopplusia orichalcea* infestation in soybean crop during *kharif*, 2011(2nd spray)

Treatments	Number of larvae/meter row length					
	1DBS	1DAS	3DAS	7DAS	10DAS	MEAN
Alika247zc @ 22g ai/ha	2.00 (1.58)	1.33 (1.34)	1.66 (1.46)	1.33 (1.34)	1.00 (1.22)	1.46 (1.38)
Alika247zc @27.5g ai/ha	1.33 (1.34)	0.33 (0.87)	0.66 (1.05)	0.33 (0.87)	0.00 (0.70)	0.53 (0.70)
Alika247zc @ 33g ai/ha	1.00 (1.22)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.20 (0.80)
Thiamethoxam 25%wg @25g ai/ha	3.66 (2.03)	3.33 (1.94)	1.66 (1.46)	1.66 (1.46)	1.33 (1.34)	2.32 (1.64)
Lambdacyhalothrin 4.9% @ 15g ai/ha	2.33 (1.67)	2.66 (1.77)	2.00 (1.55)	1.00 (1.22)	0.66 (1.05)	1.73 (1.45)
Ethion 50%EC @750g ai/ha	3.00 (1.85)	3.00 (1.85)	2.00 (1.55)	1.33 (1.34)	1.00 (1.22)	2.06 (1.56)
Imidacloprid17.8%SL @20g ai/ha	2.00 (1.55)	1.33 (1.34)	0.66 (1.05)	0.33 (0.87)	0.00 (0.70)	0.86 (1.10)
Untreated	4.33 (2.19)	5.00 (2.33)	4.00 (2.11)	3.00 (1.87)	2.00 (1.58)	3.66 (2.01)
SEm ±	.3726 (.0921)	.3303 (.1019)	.3805 (.1402)	.2480 (.1067)	.1606 (.0715)	
Cd at 5%	1.130 (.2795)	1.001 (.3092)	1.154 (.4254)	.7521 (.3237)	.4870 (.2170)	

Data in Parenthesis indicate square root transformation value $\sqrt{x+0.5}$

DBS =Days Before Spraying

DAS = Days After Spraying



Plate 1: Larva of Semilooper, *Thysanoplusia orichalcea*



Plate 2: Larva of BHC, *Spilarctia oblique*



Plate 3: Larva of Tobacco caterpillar, *Spodoptera litura*



**Plate 4: Spider preying on
defoliator larva**



**Plate 5: Adult of *Coccinella
septempunctata***



Plate 6: *Canthoconid* bug preying on lepidopterous larvae



Plate 7: Fungus infecting lepidopterous larvae



Plate 8: Lepidopterous larvae infected with NPV

and Ethion 50%EC @750g ai/ha. Thiamethoxam 25%wg @25g ai/ha was having 1.33 larvae/mrl.

On basis of overall mean Alika247zc @ 33g ai/ha, Alika247zc @27.5gai/ha and Imidacloprid17.8%SL @20g ai/ha were most effective and Thiamethoxam 25%wg @25g ai/ha was least effective.

If we look at results of 1st and 2nd spray together we can see that Alika247zc @ 33g ai/ha, Alika247zc @27.5gai/ha were best treatments but Thiamethoxam 25%wg @25g ai/ha was not much effective against *T. orichalcea*.

4.1.3 Bihar hairy caterpillar, *Spilarctia obliqua* (Walker)

The observation of population of *Spilarctia obliqua* was taken 1day before and 1,3,7 and 10 days after first spray and the results are summerised in table 4.5.

The incidence of *S. obliqua* on soybean 1 day before 1st spray varied from 1.00 to 6.33 larvae/mrl.

One day after spray, there was reduction in the population of *S. obliqua* in all the treatments except Lambdacyhalothrin 4.9% @ 15g ai/ha in which population remained same. Based on percent mortality at 1 DAS, the treatment can be put in descending order as Alika247zc @ 33g ai/ha > Alika247zc @27.5g ai/ha > Imidacloprid17.8%SL @20g ai/ha > Ethion 50%EC @750g ai/ha > Lambdacyhalothrin 4.9% @ 15g ai/ha> Thiamethoxam 25%wg @25g ai/ha > Alika247zc @ 22g ai/ha.

Three days after spray the lowest population was in Alika247zc @ 33g ai/ha followed by Alika247zc @27.5g ai/ha and Imidacloprid17.8%SL @20g ai/ha . The least control was found in untreated one followed by Alika247zc @ 22g ai/ha.

Seven days after spray the larval population in Alika247zc @ 33g ai/ha, Alika247zc @27.5gai/ha, Imidacloprid 17.8%SL@20gai/ha, Ethion 50%EC@750g ai/ha, Lambdacyhalothrin 4.9% @ 15g ai/ha, Thiamethoxam 25%wg @25g ai/ha, Alika247zc @ 22g ai/ha were 0.00, 0.33, 0.33, 1.00, 1.00, 1.00, 1.66 larvae/mrl. In untreated plot there were 2.66 larvae/mrl.

Ten days after spray Alika247zc @ 33g ai/ha and Imidacloprid 17.8%SL@20gai/ha provided cent percent control followed by Alika247zc

@27.5gai/ha having 0.33 larvae/mrl. Ethion 50%EC@750g ai/ha, Lambdacyhalothrin 4.9% @ 15g ai/ha and Thiamethoxam 25%wg @25g ai/ha were having 0.66 larvae/mrl. Of all the treatments highest population was in untreated plot followed by Alike247zc @ 22g ai/ha.

On basis of overall mean Alike247zc @ 33g ai/ha was most effective and Alike247zc @ 22g ai/ha was least effective.

The larval population during second spray is summerised in table 4.6. One day before second spray the larval population of *S. obliqua* varied from 1.00 to 5.00 larvae/mrl.

One day after spray Alike247zc @ 33g ai/ha provided 100% control. There were 0.33 larvae/mrl with Alike247zc @ 27.5g ai/ha. Ethion 50%EC@750g ai/ha and Imidacloprid17.8%SL@20 g ai/ha were having same larval population i.e. 0.66 larvae/mrl. Lambdacyhalothrin 4.9% @ 15g ai/ha have 1.00 larvae/mrl.

Three day after spray Alike247zc @ 33g ai/ha and Alike247zc @ 27.5g ai/ha gave 100% larval mortality. Ethion 50%EC@750g ai/ha, Imidacloprid 17.8%SL@20gai/ha and Lambdacyhalothrin 4.9% @ 15g ai/ha have 0.33 larvae/mrl. Thiamethoxam 25%wg @25g ai/ha have 1.00 larvae/mrl and Alike247zc @ 22g ai/ha have 1.33 larvae/mrl.

Seven days after spray there was reduction in larval population in every treatment. Highest larval population was found in Alike247zc @ 22g ai/ha and lowest larval population was found in Alike247zc @ 33g ai/ha and Alike247zc @ 27.5g ai/ha.

Ten day after spray the larval population varied from 0.00 in Alike247zc @ 33g ai/ha and Imidacloprid17.8%SL@20gai/ha to 1.00 in Alike247zc @ 22g ai/ha and 2.00 in untreated plot. Lambdacyhalothrin 4.9% @ 15g ai/ha, Thiamethoxam 25%wg @25g ai/ha and Ethion 50%EC@750g ai/ha have 0.33larvae/mrl.

On basis of larval mortality the treatments can be put in decending order as Alike247zc @ 33g ai/ha > Alike247zc @ 27.5g ai/ha> Imidacloprid 17.8%SL@20gai/ha> Ethion 50%EC@750g ai/ha > Lambdacyhalothrin 4.9% @ 15g ai/ha >Thiamethoxam 25%wg @25g ai/ha >Alike247zc @ 22g ai/ha > untreated.

Table 4.5: Effect of different treatments on *Spilarctia obliqua* infestation in soybean crop during *kharif*, 2011(1st spray)

Treatments	Number of larvae/meter row length					
	1DBS	1DAS	3DAS	7DAS	10DAS	MEAN
Alika247zc @ 22g ai/ha	4.00 (2.11)	2.33 (1.67)	2.00 (1.55)	1.66 (1.46)	1.33 (1.34)	2.26 (1.62)
Alika247zc @27.5g ai/ha	1.66 (1.44)	0.66 (1.05)	0.66 (1.05)	0.33 (0.87)	0.33 (0.87)	0.72 (1.05)
Alika247zc @ 33g ai/ha	1.00 (1.22)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.20 (0.80)
Thiamethoxam 25%wg @25g ai/ha	2.00 (1.58)	1.66 (1.46)	1.33 (1.34)	1.00 (1.22)	0.66 (1.05)	1.33 (1.33)
Lambdacyhalothrin 4.9% @ 15g ai/ha	1.33 (1.34)	1.33 (1.34)	1.00 (1.22)	1.00 (1.22)	0.66 (1.05)	1.06 (1.23)
Ethion 50%EC @750g ai/ha	1.33 (1.34)	1.00 (1.22)	1.00 (1.22)	1.00 (1.22)	0.66 (1.05)	0.99 (1.21)
Imidacloprid17.8%SL @20g ai/ha	1.66 (1.46)	1.00 (1.22)	0.66 (1.05)	0.33 (0.87)	0.00 (0.70)	0.73 (1.06)
Untreated	6.33 (2.60)	3.66 (2.03)	3.00 (1.87)	2.66 (1.77)	2.33 (1.67)	3.59 (1.98)
SEm ±	.4859 (.1338)	.2558 (.0939)	.3053 (.1229)	.2398 (.1043)	.2781 (.1280)	
Cd at 5%	1.473 (.4058)	.7760 (.2850)	.9261 (.3727)	.7275 (.3163)	.8436 (.3884)	

Data in Parenthesis indicate square root transformation value $\sqrt{x+0.5}$

DBS =Days Before Spraying

DAS = Days After Spraying

Table 4.6: Effect of different treatments on *Spilarctia obliqua* infestation in soybean crop during kharif, 2011(2nd spray)

Treatments	Number of larvae/meter row length					
	1DBS	1DAS	3DAS	7DAS	10DAS	MEAN
Alika247zc @ 22g ai/ha	3.00 (1.85)	1.33 (1.34)	1.33 (1.34)	1.33 (1.34)	1.00 (1.22)	1.59 (1.41)
Alika247zc @27.5g ai/ha	1.33 (1.34)	0.33 (0.87)	0.00 (0.87)	0.00 (0.70)	0.33 (0.87)	0.39 (0.93)
Alika247zc @ 33g ai/ha	1.00 (1.22)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.20 (0.80)
Thiamethoxam 25%wg @25g ai/ha	1.33 (1.34)	1.33 (1.34)	1.00 (1.34)	0.66 (1.05)	0.33 (0.87)	(0.93) (1.18)
Lambdacyhalothrin 4.9% @ 15g ai/ha	0.66 (1.05)	1.00 (1.22)	0.33 (1.22)	0.66 (1.05)	0.33 (0.87)	0.59 (1.08)
Ethion 50%EC @750g ai/ha	0.66 (1.05)	0.66 (1.05)	0.33 (1.05)	0.66 (1.05)	0.33 (0.87)	0.52 (1.01)
Imidacloprid17.8%SL @20g ai/ha	1.33 (1.34)	0.66 (1.05)	0.33 (1.05)	0.00 (0.70)	0.00 (0.70)	0.46 (0.96)
Untreated	5.00 (2.33)	2.66 (1.77)	2.33 (1.67)	1.66 (1.46)	2.00 (1.58)	2.73 (1.76)
SEm ±	.3908 (.1310)	.2988 (.1320)	.2672 (.1204)	.2709 (.1246)	.2480 (.1283)	
Cd at 5%	1.1854 (.3973)	.9062 (.4003)	.8105 (.3652)	.8217 (.3780)	.7521 (.3893)	

Data in Parenthesis indicate square root transformation value $\sqrt{x+0.5}$

DBS =Days Before Spraying

DAS = Days After Spraying

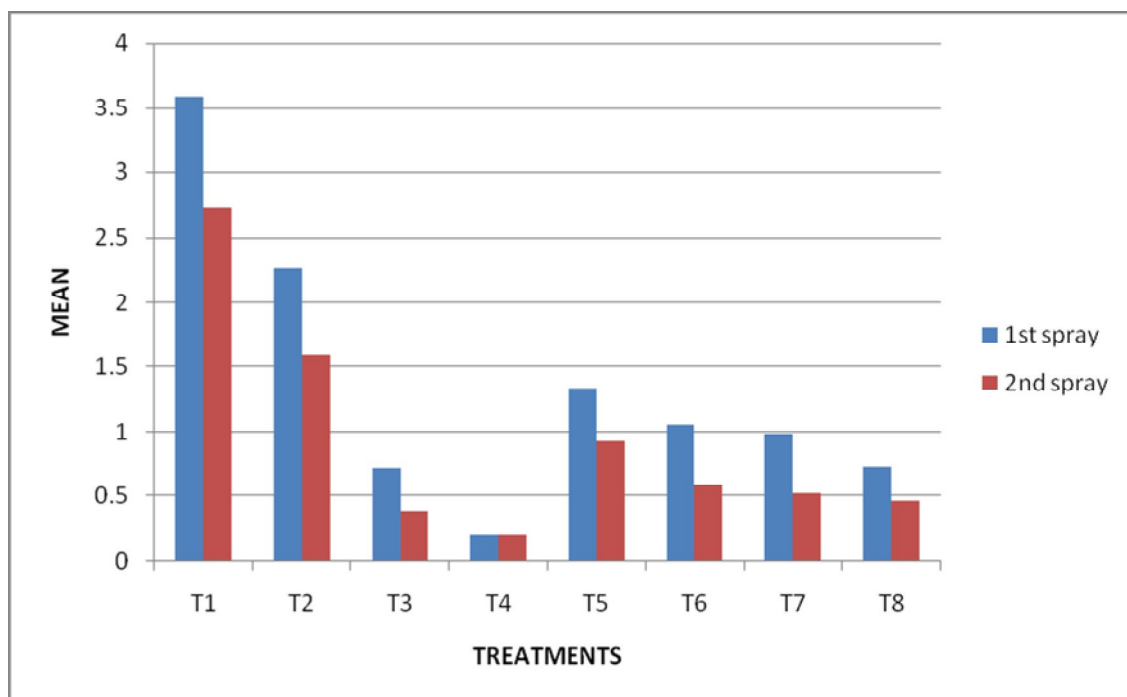


Fig. 4: Effect of different treatments on *Spilarctia obliqua* infestation in soybean crop during Kharif, 2011

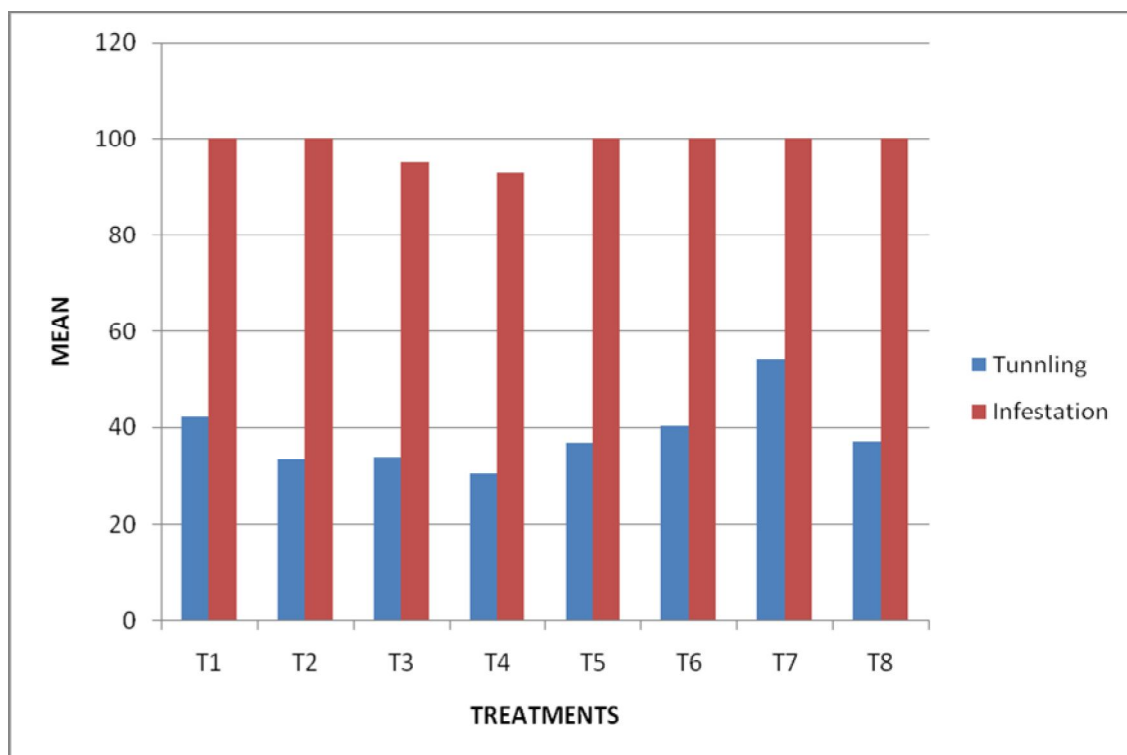


Fig. 5: Effect of different treatments on stemfly *M. sojae* in soybean crop during Kharif, 2011

Table 4.7: Effect of different treatments on stemfly, *M.sojae* in soybean crop during kharif,2011

S.No.	Treatments	Stem fly	
		Percent tunneling	Percent infestation
1	Alika247zc @ 22g ai/ha	33.45	100
2	Alika247zc @27.5g ai/ha	33.90	95
3	Alika247zc @ 33g ai/ha	30.55	93
4	Thiamethoxam 25%wg @25g ai/ha	36.93	100
5	Lambdacyhalothrin 4.9% @ 15g ai/ha	40.38	100
6	Ethion 50%EC @750g ai/ha	54.49	100
7	Imidacloprid17.8%SL @20g ai/ha	37.20	100
8	Untreated	42.32	100

Table 4.8: Effects of different treatments on yield of soybean crop during *Kharif*-2011

TREATMENTS	YIELD (q/ha)
Thiamethoxam12.6+Lambdacyhalothrin 9.5%ZC (Alika247ZC) @22g ai/ha	14.85
Thiamethoxam12.6+Lambdacyhalothrin 9.5%ZC (Alika247ZC) @27.5g ai/ha	15.33
Thiamethoxam12.6+Lambdacyhalothrin 9.5%ZC (Alika247ZC) @33 g ai/ha	14.67
Thimethaoxam 25%WG@25 g ai/ha	12.00
Lambdacyhalothrin 4.9%@15 g ai/ha	12.56
Ethion 50% EC@750 g ai/ha	9.33
Imidacloprid 17.8% SL@20 g ai/ha	7.35
Untreated control	8.50

The maximum mortality of *S. obliqua* during both the sprays was recorded in case of Alika247zc @ 33g ai/ha and Alika247zc @ 27.5g ai/ha and least mortality was recorded in Alika247zc @ 22g ai/ha. While Imidacloprid17.8%SL@20gai/ha, Ethion 50%EC@750g ai/ha, Lambdacyhalothrin 4.9% @ 15g ai/ha and Thiamethoxam 25%wg @25g ai/ha gave satisfactory results.

4.2 Stem borer

4.2.1 Stem Fly *Melanagromyza sojae*

The data on per cent stem tunneling and infested plant percentage by stem fly under different treatments were taken at the time of harvest (table-4.7).

Mean percent of stem tunneling indicated that, Alika247zc @ 33g ai/ha gave maximum control with 30.55% stem tunneling and 93% infestation. 33.90% stem tunneling and 95% infestation was found in Alika247zc @ 27.5g ai/h. In Alika247zc @ 22g ai/ha 100% infestation and 33.45% stem tunneling was found. In other treatments viz. Imidacloprid17.8%SL@20gai/ha, Ethion 50%EC@750g ai/ha, Lambdacyhalothrin 4.9% @ 15g ai/ha, Thiamethoxam 25%wg @25g ai/ha 37.20, 54.49, 40.38, 36.93 % stem tunneling and 100% infestation was recorded.

On the basis of percent plant infestation Alika247zc @ 33g ai/ha, Alika247zc @ 27.5g ai/h and Alika247zc @ 22g ai/ha were found to be effective for reducing the stem fly infestation to some extent.

4.3 Yield

The effect of different treatments on the grain yield was significant at probability 0.05 (table-4.8). However maximum grain yield was obtained 15.33q/ha in Alika247zc @ 27.5g ai/h followed by 14.85q/ha in Alika247zc @ 22g ai/ha. On the basis of yield the treatments can be ranked in descending order as Alika247zc @ 27.5g ai/h> Alika247zc @ 22g ai/ha> Alika247zc @ 33g ai/ha> Lambdacyhalothrin 4.9% @ 15g ai/ha >Thiamethoxam 25%wg @25g ai/ha> Ethion 50%EC@750g ai/ha> Imidacloprid17.8%SL@20g ai/ha. In untreated plot yield obtained was 8.50 q/ha. The higher yield of Alika247zc @ 27.5g ai/h and Alika247zc @ 22g ai/ha was due to better insect pest management in these plot.

4.4 Effect on natural enemies

Predators and parasitoids are the natural enemies which attack various life stages of insect pests and help to check population build up of pest. During observation in soybean field many predators were encountered. These were spider, coccinellids, canthoconid bug and undetermined predatory wasp. While among parasitoid, *Apanteles* sp. and an unidentified ichneumonid were prevalent.

The impact of different treatments on major predators i.e. spider and coccinellids was assessed and presented in tables 4.9 to 4.12.

4.4.1 Ladybird beetle, *Coccinella* sp.

Effect of different treatment on *Coccinella* population was recorded 1 day before and 1, 3, 7 and 10 day after first spray and results are summerised in table 4.9.

One day before 1st spray, the mean *Coccinella* spp. population varied significantly at probability 0.05, from 1.00 to 4.00 adult or grubs/mrl.

1 day after spraying, *Coccinella* population varied from 0.45 to 0.85 grubs /mrl. There was slight decrease in *Coccinella* population noticed in plots treated with Alika247zc @ 27.5g ai/h (from 4.00 to 1.33grubs/mrl), Alika247zc @ 22g ai/ha (3.66 to 2.00grubs/mrl), Alika247zc @ 33g ai/ha (1.33 to 1.00grubs/mrl) and Ethion 50%EC @750g ai/ha (from1.66 to 1.33grubs/mrl). In Lambdacyhalothrin 4.9% @ 15g ai/ha and Thiamethoxam 25%wg @25g ai/ha the coccinellid population remains the same before and after spray. While in Imidacloprid17.8%SL @20g ai/ha the coccinellid population increased from 1.00 to 1.33 grubs/mrl.

Three days after spray the treatments can be put in descending order according to grub population as untreated > Alika247zc @ 27.5g ai/h = Alika247zc @ 33g ai/ha = Lambdacyhalothrin 4.9% @ 15g ai/ha = Thiamethoxam 25%wg @25g ai/ha > Alika247zc @ 22g ai/h = Ethion 50%EC @750g ai/ha = Imidacloprid17.8%SL @20g ai/ha.

Seven days after spray the grub population was 1.00grub/mrl in Imidacloprid 17.8%SL @20g ai/ha to 2.33grub/mrl in Lambdacyhalothrin 4.9% @ 15g ai/ha.

Table 4.9: Effect of different treatments on population of *Coccinella* sp. in soybean crop during *kharif*, 2011 (1st spray)

Treatments	Number of larvae/meter row length					
	1DBS	1DAS	3DAS	7DAS	10DAS	MEAN
Alika247zc @ 22g ai/ha	3.66 (2.03)	2.00 (1.55)	1.33 (1.34)	1.33 (1.34)	1.66 (1.44)	1.99 (1.54)
Alika247zc @27.5g ai/ha	4.00 (2.11)	1.33 (1.34)	1.66 (1.46)	1.83 (1.50)	2.06 (1.57)	2.17 (1.59)
Alika247zc @ 33g ai/ha	1.33 (1.34)	1.00 (1.22)	1.66 (1.38)	1.33 (1.34)	1.33 (1.34)	1.33 (1.32)
Thiamethoxam 25%wg @25g ai/ha	2.00 (1.55)	2.00 (1.55)	1.66 (1.46)	2.00 (1.55)	2.33 (1.65)	1.99 (1.55)
Lambdacyhalothrin 4.9% @ 15g ai/ha	1.33 (1.34)	1.33 (1.34)	1.66 (1.46)	2.33 (1.67)	3.00 (1.85)	1.93 (1.53)
Ethion 50%EC @750g ai/ha	1.66 (1.46)	1.33 (1.34)	1.33 (1.77)	1.66 (1.46)	1.66 (1.46)	1.52 (1.49)
Imidacloprid17.8%SL @20g ai/ha	1.00 (1.22)	1.33 (1.46)	1.33 (1.34)	1.00 (1.22)	1.16 (1.28)	1.16 (1.30)
Untreated	3.33 (1.95)	2.66 (1.77)	2.00 (1.55)	1.66 (1.46)	2.00 (1.55)	2.33 (1.65)
SEm ±	.4008 (.1156)	.3535 (.1182)	.9008 (.2846)	.3528 (.1185)	.5110 (.1645)	
Cd at 5%	1.215 (.3508)	1.072 (.3585)	2.7321 (.8633)	1.070 (.3594)	1.5499 (.4991)	

Data in Parenthesis indicate square root transformation value $\sqrt{x+0.5}$

DBS =Days Before Spraying

DAS = Days After Spraying

Table 4.10: Effect of different treatments on population of *Coccinella* sp. in soybean crop during *kharif*, 2011 (2nd spray)

Treatments	Number of <i>Coccinella</i> /meter row length					
	1DBS	1DAS	3DAS	7DAS	10DAS	MEAN
Alika247zc @ 22g ai/ha	2.66 (1.77)	1.66 (1.46)	1.66 (1.46)	1.43 (1.38)	2.00 (1.58)	1.88 (1.53)
Alika247zc @27.5g ai/ha	3.00 (1.85)	2.66 (1.73)	2.16 (1.60)	1.73 (1.49)	2.16 (1.62)	2.34 (1.65)
Alika247zc @ 33g ai/ha	1.33 (1.34)	2.00 (1.55)	2.13 (1.61)	2.30 (1.66)	2.16 (1.62)	1.98 (1.55)
Thiamethoxam 25%wg @25g ai/ha	1.33 (1.34)	2.66 (1.76)	2.56 (1.78)	2.30 (1.66)	2.53 (1.73)	2.27 (1.65)
Lambdacyhalothrin 4.9% @ 15g ai/ha	1.00 (1.22)	1.33 (1.72)	1.56 (1.42)	1.06 (1.48)	2.03 (1.57)	1.39 (1.48)
Ethion 50%EC @750g ai/ha	0.66 (1.05)	1.56 (1.39)	1.73 (1.48)	2.13 (1.61)	2.40 (1.78)	1.69 (1.46)
Imidacloprid17.8%SL @20g ai/ha	0.66 (1.05)	1.70 (1.47)	2.00 (1.59)	1.66 (1.38)	2.33 (1.56)	1.67 (1.41)
Untreated	2.33 (1.67)	1.66 (1.46)	1.66 (1.46)	1.60 (1.44)	2.33 (1.67)	1.91 (1.54)
SEm ±	.3700 (.1314)	.9375 (.2609)	.4085 (.1330)	.4302 (.1555)	.5886 (.1956)	
Cd at 5%	1.1221 (.3985)	2.843 (.7914)	1.2391 (.4035)	1.3047 (.4719)	1.7859 (.5932)	

Data in Parenthesis indicate square root transformation value $\sqrt{x+0.5}$

DBS =Days Before Spraying

DAS = Days After Spraying

Ten days after spray the coccinellid population varied in all treatments. It was highest in Lambdacyhalothrin 4.9% @ 15g ai/ha (3.00/mrl) followed by Thiamethoxam 25%wg @25g ai/ha having 2.33 *Coccinella*/mrl and Alika247zc @27.5g ai/ha having 2.06 coccinellid/mrl. In untreated plot the coccinellid population was 2.00/mrl. Alika247zc @ 22g ai/h and Ethion 50%EC @750g ai/ha were at par with each other having 1.66 *Coccinella*/mrl. Alika247zc @ 33g ai/ha have 1.33 *Coccinella*/mrl. Lowest coccinellid population was 1.16 *Coccinella*/mrl in Imidacloprid17.8%SL @20g ai/ha.

On the basis of overall mean of coccinellid population treatments can be arranged in ascending order as Imidacloprid17.8%SL @20g ai/ha < Alika247zc @ 33g ai/ha < Ethion 50%EC @750g ai/ha < Lambdacyhalothrin 4.9% @ 15g ai/ha < Thiamethoxam 25%wg @25g ai/ha = Alika247zc @ 22g ai/h < Alika247zc @27.5g ai/ha < untreated plot.

Observation of coccinella population was taken on 1 day before and 1,3,7 and 10 day after second spray and the results were summerised in table 4.10. One day before the 2nd spray the coccinellid population varied from 0.66 to 3.00 *Coccinella*/mrl and it varied in every treatment.

One day after 2nd spray, the lowest population was found 1.33 *Coccinella*/mrl in Lambdacyhalothrin 4.9% @ 15g ai/ha followed by Ethion 50%EC @750g ai/ha having 1.56 *Coccinella*/mrl. There were 1.66 *Coccinella*/mrl in Alika247zc @ 22g ai/h and untreated one. Imidacloprid 17.8%SL @20g ai/ha have 1.70 *Coccinella*/mrl and Alika247zc @ 33g ai/ha have 2.00 *Coccinella*/mrl. The highest coccinellid population was 2.66grubs/mrl in Thiamethoxam 25%wg @25g ai/ha and Alika247zc @27.5g ai/ha.

Three days after second spray the treatments can be put in descending order of *Coccinella* population as Alika247zc @ 33g ai/ha = Thiamethoxam 25%wg @25g ai/ha > Ethion 50%EC @750g ai/ha > Alika247zc @27.5g ai/ha > Imidacloprid17.8%SL @20g ai/ha > Untreated > Alika247zc @ 22g ai/ha > Lambdacyhalothrin 4.9% @ 15g ai/ha.

Seven days after spray the population of *Coccinella* varied in most of the treatments. It was 1.06, 1.43, 1.60, 1.66, 1.73 and 2.13 *Coccinella*/mrl in

Lambdacyhalothrin 4.9% @ 15g ai/ha, Alika247zc @ 22g ai/ha, Untreated, Imidacloprid17.8%SL @20g ai/ha, Alika247zc @27.5g ai/ha and Ethion 50%EC @750g ai/ha respectively. Thiamethoxam 25%wg @25g ai/ha and Alika247zc @ 33g ai/ha were at par with each other having 2.30 *Coccinella*/mrl.

Ten day after spray the coccinelled population increased variably in every treatment as compared to 7DAS. It varied from 2.53 *Coccinella*/mrl in Thiamethoxam 25% wg @25g ai/ha to 2.03 *Coccinella*/mrl in Lambdacyhalothrin 4.9% @ 15g ai/ha.

On the basis of overall mean coccinellid population the treatments can be arranged in ascending order as Lambdacyhalothrin 4.9% @ 15g ai/ha < Imidacloprid17.8%SL @20g ai/ha < Ethion 50%EC @750g ai/ha < Alika247zc @ 22g ai/ha < Untreated < Alika247zc @ 33g ai/ha < Thiamethoxam 25%wg @25g ai/ha < Alika247zc @27.5g ai/ha.

4.4.2 Effect on spider population

The spider population was taken 1 day before and 1,3,7 and 10 days after 1st spray and the results are summarised in table 4.11. One day before 1st spray, the spider population varied significantly at probability 0.05, from 1.00 to 3.00 spiders/mrl.

One day after spray in untreated plot the spider population was 1.00 spider/mrl. In other treatments it was 1.33, 1.66, 1.66, 1.33, 1.66, 1.66 and 1.33 spiders/mrl in Alika247zc @ 22g ai/ha, Alika247zc @27.5g ai/ha, Alika247zc @ 33g ai/ha, Thiamethoxam 25%wg @25g ai/ha, Lambdacyhalothrin 4.9% @ 15g ai/ha, Ethion 50%EC @750g ai/ha, Imidacloprid17.8%SL @20g ai/ha respectively.

Three day after spray the population of spider was lowest in Imidacloprid17.8%SL @20g ai/ha (0.76 spiders/mrl). The spider population was highest in Thiamethoxam 25%wg @25g ai/ha (2.00 spiders/mrl)

On the basis of spider population seven days after spray, the treatments can be arranged in ascending order as Alika247zc @27.5g ai/ha< Thiamethoxam 25%wg @25g ai/ha = Ethion 50%EC @750g ai/ha < Alika247zc @ 33g ai/ha < Imidacloprid17.8%SL @20g ai/ha < Untreated < Alika247zc @ 22g ai/ha = Lambdacyhalothrin 4.9% @ 15g ai/ha.

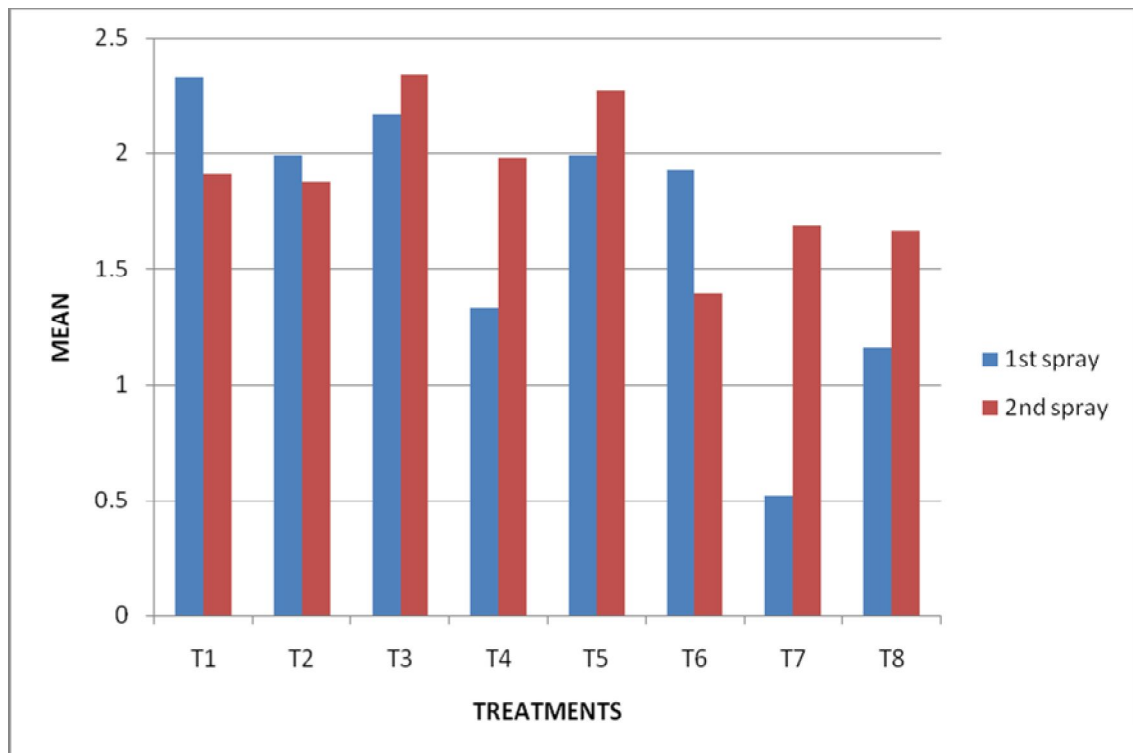


Fig. 6: Effect of different treatments on population of *Coccinella sp.* in soybean crop during Kharif, 2011

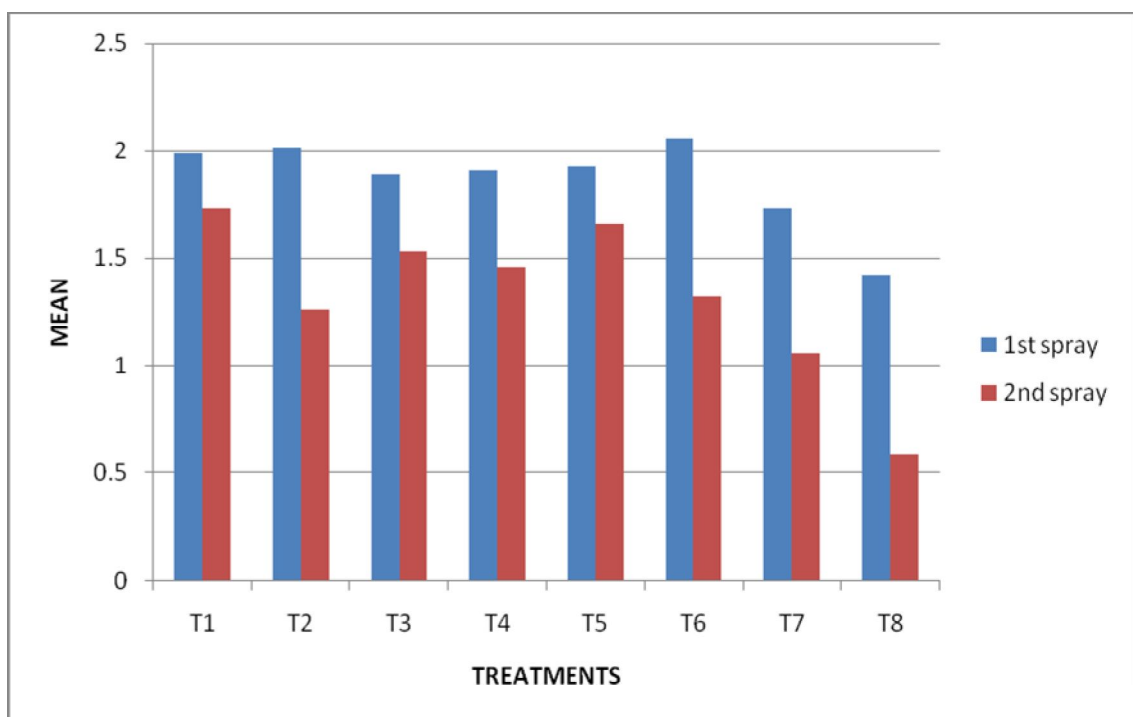


Fig. 7: Effect of different treatments on population of spiders in soybean crop during Kharif, 2011

Table 4.11: Effect of different treatments on population of spider in soybean crop during *kharif*, 2011 (1st spray)

Treatments	Number of spiders/meter row length					
	1DBS	1DAS	3DAS	7DAS	10DAS	MEAN
Alika247zc @ 22g ai/ha	2.66 (1.77)	1.33 (1.46)	1.66 (1.44)	2.33 (1.59)	2.10 (1.58)	2.01 (1.56)
Alika247zc @27.5g ai/ha	3.00 (1.85)	1.66 (1.46)	1.66 (1.46)	1.33 (1.34)	1.83 (1.50)	1.89 (1.52)
Alika247zc @ 33g ai/ha	1.66 (1.46)	1.66 (1.34)	1.86 (1.51)	1.73 (1.49)	2.66 (1.76)	1.91 (1.51)
Thiamethoxam 25%wg @25g ai/ha	2.66 (1.76)	1.33 (1.46)	2.00 (1.55)	1.66 (1.44)	2.00 (1.35)	1.93 (1.51)
Lambdacyhalothrin 4.9% @ 15g ai/ha	2.00 (1.55)	1.66 (1.46)	2.00 (1.55)	2.33 (1.64)	2.33 (1.46)	2.06 (1.53)
Ethion 50%EC @750g ai/ha	2.00 (1.58)	1.66 (1.34)	1.33 (1.34)	1.66 (1.46)	2.00 (1.55)	1.73 (1.45)
Imidacloprid17.8%SL @20g ai/ha	1.00 (1.22)	1.33 (1.05)	0.76 (1.11)	1.86 (1.53)	2.16 (1.62)	1.42 (1.30)
Untreated	2.66 (1.77)	1.00 (1.46)	1.33 (1.34)	2.00 (1.52)	3.00 (1.78)	1.99 (1.57)
SEm ±	.3646 (.1071)	.3362 (.1290)	.5009 (.1664)	.5499 (.1619)	.8333 (.2600)	
Cd at 5%	1.1058 (.3249)	1.019 (.3915)	1.5192 (.5047)	1.667 (.4911)	2.5275 (.7887)	

Data in Parenthesis indicate square root transformation value $\sqrt{x + 0.5}$

DBS =Days Before Spraying

DAS = Days After Spraying

Table 4.12: Effect of different treatments on population of spider in soybean crop during *kharif*, 2011 (2nd spray)

Treatments	Number of spiders/meter row length					
	1DBS	1DAS	3DAS	7DAS	10DAS	MEAN
Alika247zc @ 22g ai/ha	0.33 (0.87)	1.66 (1.46)	1.33 (1.34)	1.66 (1.46)	1.33 (1.34)	1.26 (1.29)
Alika247zc @27.5g ai/ha	2.33 (1.67)	2.00 (1.55)	1.00 (1.22)	1.00 (1.22)	1.33 (1.34)	1.53 (1.4)
Alika247zc @ 33g ai/ha	2.00 (1.55)	1.33 (1.34)	1.66 (1.44)	1.00 (1.22)	1.33 (1.34)	1.46 (1.37)
Thiamethoxam 25%wg @25g ai/ha	1.66 (1.44)	2.00 (1.55)	1.33 (1.34)	2.00 (1.55)	1.33 (1.34)	1.66 (1.44)
Lambdacyhalothrin 4.9% @ 15g ai/ha	0.66 (1.05)	1.66 (1.46)	1.33 (1.34)	1.66 (1.46)	1.33 (1.34)	1.32 (1.33)
Ethion 50%EC @750g ai/ha	0.66 (1.05)	1.33 (1.34)	1.33 (1.34)	1.00 (1.22)	1.00 (1.22)	1.06 (1.23)
Imidacloprid17.8%SL @20g ai/ha	0.33 (0.87)	0.66 (1.05)	0.66 (1.05)	0.66 (1.05)	0.66 (1.05)	0.59 (1.01)
Untreated	1.00 (1.22)	2.33 (1.67)	1.33 (1.34)	2.33 (1.67)	1.66 (1.46)	1.73 (1.47)
SEm ±	.3450 (.1308)	.3086 (.1061)	.3673 (.1322)	.2709 (.1020)	.2954 (.1152)	
Cd at 5%	1.046 (.3967)	.9359 (.3220)	1.114 (.4011)	.8217 (.3094)	.8961 (.3494)	

Data in Parenthesis indicate square root transformation value $\sqrt{x+0.5}$

DBS =Days Before Spraying

DAS = Days After Spraying

Ten days after spray the population of spider was 3.00, 2.10, 1.83, 2.66, 2.00, 2.33, 2.00, 2.16 in Untreated, Alika247zc @ 22g ai/ha, Alika247zc @ 27.5g ai/ha, Alika247zc @ 33g ai/ha, Thiamethoxam 25%wg @25g ai/ha, Lambdacyhalothrin 4.9% @ 15g ai/ha, Ethion 50%EC @750g ai/ha, Imidacloprid17.8%SL @20g ai/ha respectively.

On basis of overall mean the treatment can be arranged in descending order as Lambdacyhalothrin 4.9% @ 15g ai/ha > Alika247zc @ 22g ai/ha > Untreated > Thiamethoxam 25%wg @25g ai/ha > Alika247zc @ 33g ai/ha > Alika247zc @27.5g ai/ha > Ethion 50%EC @750g ai/ha > Imidacloprid17.8%SL @20g ai/ha.

The results of spider population taken during 1 day before and 1,3,7 and 10 days after 2nd spray are summerised in table 4.12. One day before second spray the spider population varied significantly from 0.33 to 2.33 spiders/mrl.

One day after second spray the spider population in different treatment was 0.66 spiders/mrl in Imidacloprid17.8%SL @20g ai/ha followed by 1.33 spiders/mrl in Ethion 50%EC @750g ai/ha and Alika247zc @ 33g ai/ha and 1.66 spiders/mrl in Alika247zc @ 22g ai/ha and Lambdacyhalothrin 4.9% @ 15g ai/ha.

Three day after spray the spider population was 1.33spiders/mrl in most of the treatments except in Alika247zc @ 33g ai/ha (1.66 spiders/mrl), Alika247zc @27.5g ai/ha (1.00 spiders/mrl) and Imidacloprid17.8%SL @20g ai/ha (0.66 spiders/mrl).

Seven days after spray the spider population was maximum in untreated plot (2.33 spider/mrl) and it was lowest in Imidacloprid17.8%SL @20g ai/ha (0.66 spiders/mrl).

Ten days after spray spider population ranges from 0.66 spider/mrl in Imidacloprid17.8%SL @20g ai/ha to 1.66 spiders/mrl in untreated plot. All other treatments were at par with each other.

On the basis of overall mean spider population the treatments can be put in descending order as untreated > Thiamethoxam 25%wg @25g ai/ha > Alika247zc @27.5g ai/ha > Alika247zc @ 33g ai/ha > Lambdacyhalothrin 4.9% @ 15g ai/ha > Alika247zc @ 22g ai/ha > Ethion 50%EC @750g ai/ha> Imidacloprid17.8%SL @20g ai/ha.

4.5 Discussion

Conventional insecticides such as chlorinated hydrocarbons, organophosphates, carbamates and pyrethroids have been found successful in controlling insect pests during past five decades. Unfortunately, many insects have generated resistance against these conventional insecticides and also many of these chemicals are harmful to men and beneficial organisms and cause ecological imbalance. So efforts have been made to reduce the risk of resistance and harmful effect of insecticides. Accordingly, many conventional pesticides have been replaced by newer bio rational pesticides. According to **Hera (2000)**, bio rational or “low risk” insecticides effectively control insect pests and have low toxicity to non target organisms (such as human, animals and natural enemies) and the environment.

In the following experiment several insecticides were taken with novel mode of action. Out of all Alika247zc @27.5g ai/ha and Alika247zc @ 33g ai/ha were most effective similar results was recorded by **Hemlata Martoliya (2011)**, in her experiment she used leaf dip method to determine the efficacy of 2 insecticides viz. Coragen and Alika. She recorded that after 48 hours after exposure, Coragen (chlorantraniprole (LC₅₀ =0.45 ppm) was less toxic insecticide than Alika (thiamethoxam 12.6+lambda-cyhalothrin 9.5 %) (LC₅₀ = 0.15 ppm). The order of toxicity at both LC levels was Alika> Coragen. Not much work has been done using Alika as chemical control.

Lambda-cyhalothrin 4.9% @ 15g ai/ha and Ethion 50%EC @750g ai/ha were significantly toxic to these insects. Similar results were obtained in Bioassay studies carried out in the laboratory by **Singh et al. (2002)** to determine the relative toxicity of synthetic pyrethroids (decamethrin, cypermethrin, lambda-cyhalothrin, fenvalerate, and bifenthrin) and non-pyrethroids (endosulfan, chlorpyrifos, lindane, and malathion) against the 2nd instar larvae of *S. litura*. The order of toxicity of the insecticides against *S. litura* was lambda-cyhalothrin> decamethrin> cypermethrin> bifenthrin> chlorpyrifos> fenvalerate> malathion> endosulfan> lindane.

In case of *S.obliqua* Lambda-cyhalothrin 4.9% @ 15g ai/ha was more toxic than Thiamethoxam 25%wg @25g ai/ha and Alika247zc @ 22g ai/ha but less toxic than

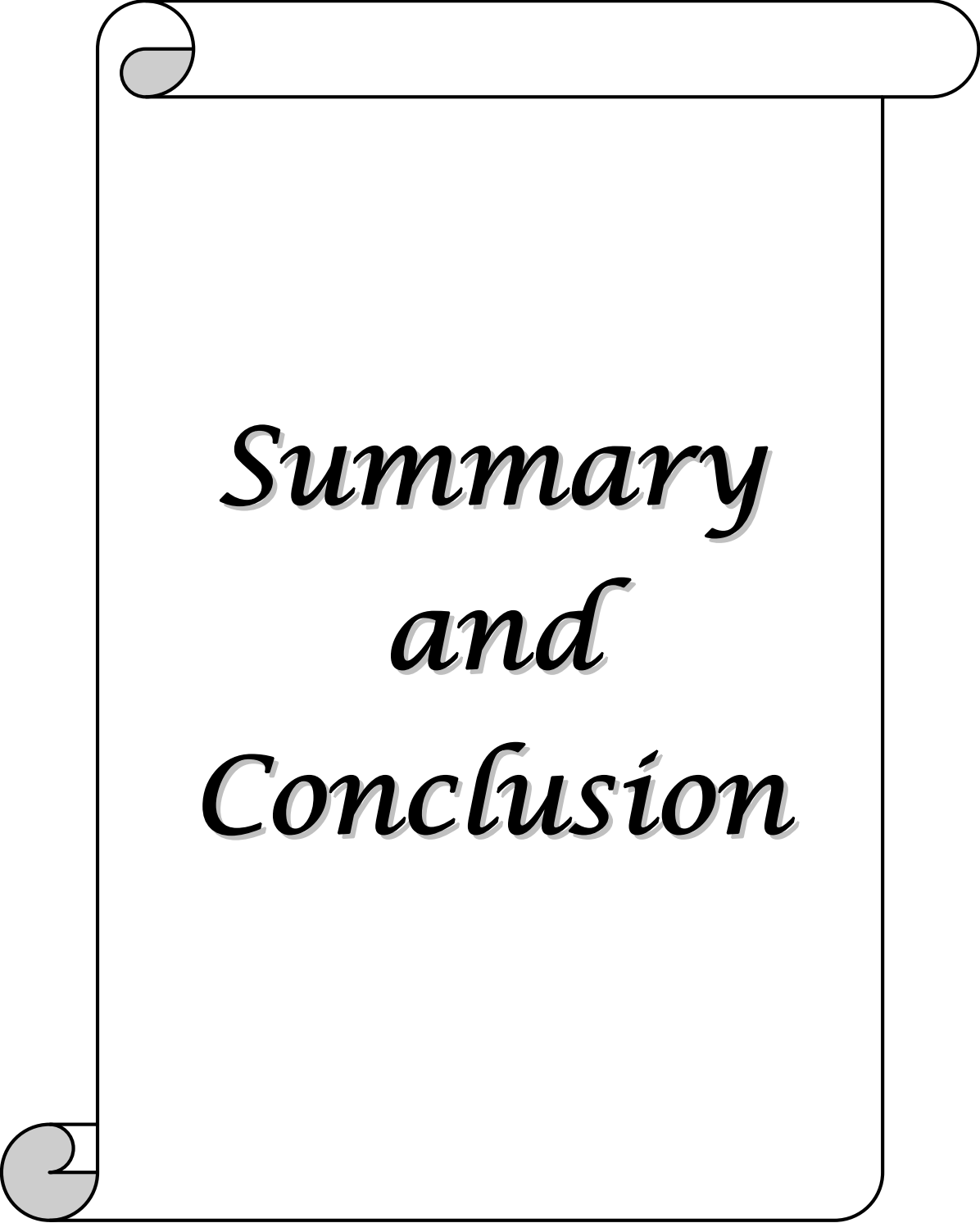
Alika247zc @ 33g ai/ha, Alika247zc @27.5g ai/ha and Imidacloprid17.8%SL @20g ai/ha . These results were similar to experiment conducted by **Singh and Singh (2000)** in which they determined the relative toxicities of ten insecticides to third instar larvae of *S.obliqua* by direct spray method under laboratory conditions. It was calculated by taking LC50 values of Lindane as unity. The synthetic pyrethroids were more toxic than the non-pyrethroids insecticides. On the basis of the LC50 values, the order of toxicity in descending order was deltamethrin> beta- cyfluthrin> fenvalerate> lambda-cyhalothrin> cypermethrin> bifenthrin> chlorpyrifos> lindane> endosulfan> malathion.

Natural enemies play vital role in controlling pest population and maintaining ecological balance so there is great demand for safe and more selective insecticides that spare natural enemies and non target organisms (**Reitz et al., 1999**).

In the present experiment Alika247zc @27.5g ai/ha was less toxic to *coccinella* population while Imidacloprid17.8%SL @20g ai/ha was highly toxic to both *coccinella* and spider population.

Thiamethoxam 25%wg @25g ai/ha was much safer as compared to Imidacloprid17.8%SL @20g ai/ha for both spider and *coccinella* population. Similar results were obtained by **P. Chandramani et al. (2007)**, he tested the recommended dose of spinosad, cypermethrin, imidacloprid, thiomethoxam, dimethoate, monocrotophos, endosulphan, neem oil, neem seed kernel extract (NSKE) and pungam oil for oral toxicity against Indian honey bee [*Apis cerana indica* (F.)] under laboratory conditions. The oral toxicity studies revealed that the toxicity of insecticides, neonicotinoid compounds and selective botanicals to *Apis cerana indica* increased with time. The descending order of oral toxicities of 10 test insecticides is cypermethrin> monocrotophos> endosulphan> dimethoate> thiomethoxam> imidacloprid> spinosad> pungam oil> neem oil and NSKE.

Similarly a field experiment was conducted by **Deshpande et al. (2007)** at oilseed Research Station, Latur during Kharif 2007 and 2008, to study the efficacy of thimethoxam 30FS seed treatment against early sucking pest, beneficial insects and impact on germination in sunflower. Thimethoxam 30FS was found safer to natural enemies and did not exhibit any phytotoxicity even at higher doses tested suggesting that it is safe to sunflower crop.



Summary and Conclusion

Comparative efficacy of some insecticides against insect pests of soybean under field condition was studied at Norman E. Borlaug Crop Research Centre, Pantnagar during *kharif*, 2011.

A total of eleven insect pests were found to attack soybean crop. Out of these 5 species viz. tobacco caterpillar, Bihar hairy caterpillar, green semilooper, leaf folder and grey weevil were foliage feeders, 2 species viz., stem fly and girdle beetle belong to stem feeders where as 4 species viz., whitefly, aphid, jassid and green stink bug were sucking pests.

Observations on larval population of Bihar hairy caterpillar, tobacco caterpillar, green semilooper, along with spiders and coccinellids adult and grub were taken one day before and 1, 3, 7 and 10 days after spraying.

Alika247zc @ 33g ai/ha and Alika247zc @27.5g ai/ha successfully controlled the populations of *Spodoptera litura*. However Thiamethoxam 25%wg @25g ai/ha, Lambdacyhalothrin 4.9% @ 15g ai/ha, Ethion 50%EC @750g ai/ha and Imidacloprid17.8%SL @20g ai/ha show slight toxicity against this pest while Alika247zc @ 22g ai/ha showed very low toxicity towards *S. litura*.

100 % control of *T. orichalcea* was exhibited by Alika247zc @ 33g ai/ha and lower doses of this insecticide also recorded a significant reduction in the larval population of this pest.

Larvae of *S. obliqua* were successfully controlled by Alika247zc @ 33g ai/ha and Alika247zc @27.5g ai/ha. However Alika247zc @ 22g ai/ha did not give much satisfactory results. Imidacloprid17.8%SL @20g ai/ha and Ethion 50%EC @750g ai/ha also gave significant reduction in the larval population of this pest.

Results revealed that two treatments of Alika 247zc were effective against defoliators of soybean and highest dose of Alika247zc @ 33g ai/ha showed cent.

percent mortality of larval populations and its lower dose Alika247zc @27.5g ai/ha a significant control over the insect pests under study but its lowest dose Alika247zc @ 22g ai/ha did not gave significant results.

The data on per cent infestation and stem tunnelling due to maggots of stem fly was taken at the time of harvest and the data indicates that higher dose of Alika i.e. Alika247zc @ 33g ai/ha followed by Alika247zc @ 22g ai/ha and Alika247zc @27.5g ai/ha was helpful in reduction of stem tunnelling. Thiamethoxam 25%wg @25g ai/ha and Imidacloprid17.8%SL @20g ai/ha were also found effective to some extent against stem fly. No one chemical was found highly effective against stemfly infestation.

Recommendation of the treatment Alika247zc @27.5g ai/ha Alika247zc @ 22g ai/ha is safe because of its less toxicity to *Coccinella spp.* and spider population respectively.

Observation on predators of soybean insect pests showed that no test chemical had a detrimental effect on the population of predators except Imidacloprid17.8%SL @20g ai/ha. However, Alika247zc was safest to spiders and coccinellids at all doses. Imidacloprid17.8%SL was highly toxic to the natural enemies.

Maximum yield was obtained in the plots treated with Alika247zc @27.5g ai/ha followed by Alika247zc @ 22g ai/ha, Alika247zc @ 33g ai/ha, Lambdacyhalothrin 4.9% @ 15g ai/ha, Thiamethoxam 25%wg @25g ai/ha, Ethion 50%EC @750g ai/ha, untreated and minimum yield was obtained in case of Imidacloprid17.8%SL @20g ai/ha.

As far as insects are concerned these were effectively controlled by Alika247zc @ 33g ai/ha followed by Alika247zc @27.5g ai/ha. Least threat to natural enemies viz. spiders and coccinellids was with Alika247zc @27.5g ai/ha followed by Alika247zc @ 22g ai/ha while Imidacloprid17.8%SL pose maximum danger to these natural enemies. Highest yield was obtained in plot treated with Alika247zc @27.5g ai/ha. Hence Alika247zc @27.5g ai/ha showed great potential in Soybean IPM with less disruptive effect on natural enemies.

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VITA

The authoress was born on the 2nd of November, 1987 at District Pithoragarh (Uttarakhand). She passed her High School and Intermediate examination from Soar Valley Public School, District Pithoragarh (Uttarakhand) in 2002 and 2004, respectively. She was admitted in July, 2006 at the G.B. Pant University of Agriculture and Technology, Pantnagar for B.Sc. Agriculture and completed the degree in June, 2010. Later she joined the Department of Entomology in the above university for M.Sc. degree programme in Entomology in August, 2010.

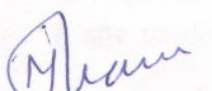
Address for Correspondence:

Akanksha Chand
D/O of Sri S. Chand
Near Beersheba School
G.I.C. Road
Pithoragarh (Uttarakhand)
Pin Code-262501
e-mail-chandakanksha51@gmai

ABSTRACT

Name : Akanksha Chand **Id. No.** : 33050
Semester and : I, 2010-11 **Degree** : M.Sc. (Ag)
Year of Admission **Deptt.** : Entomology
Major : Entomology
Advisor : Dr. Neeta Gaur
Thesis Title : “Bioefficacy of some neonicotinoid, organophosphate and pyrethroid against insect pests of soybean”

The present investigation was carried out at Norman E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar during 2011. Soybean is an important legume, providing 43 percent protein and 20 per cent oil. It is attacked by 273 insect pests, hampering the crop production. Thus it is necessary to control insect pests of soybean. In the present experiment we used different insecticides to control the insect pest of soybean. Results showed that overall defoliators population (*Spodoptera litura*, *Thysanoplusia orichalcea* and *Spilarctia obliqua*) was effectively checked by Alika247zc @ 33g ai/ha and Alika247zc @27.5g ai/ha. Thiamethoxam 25%wg @25g ai/ha, Lambda cyhalothrin 4.9% @ 15g ai/ha, Ethion 50%EC @750g ai/ha and Imidacloprid 17.8%SL @20g ai/ha show slight toxicity against these pest while Alika247zc @ 22g ai/ha showed very low toxicity. Alika247zc @ 33g ai/ha was most toxic to stem fly. Treatment of Alika247zc @27.5g ai/ha and Alika247zc @ 22g ai/ha is safe because of its less toxicity to *Coccinella spp.* and spider population respectively but Imidacloprid 17.8%SL was highly toxic to the natural enemies. Maximum yield was obtained in the plots treated with Alika247zc @27.5g ai/ha because of the better management of insect pests. Thus the present investigation revealed that use of Alika247zc @27.5g ai/ha showed potential in Soybean IPM with less disruptive effect on natural enemies viz., Spider and coccinellids.


(Neeta Gaur)
Advisor


(Akanksha Chand)
Authoress

सारांश

नाम : आकांक्षा चन्द्र परिचयांक : 33050
प्रवेश वर्ष एवं षट्मास: 2010-11, प्रथम उपाधि : स्नातकोत्तर (शि)
मुख्य विषय : कीट विज्ञान विभाग : कीट विज्ञान
शोध शीर्षक : सोयाबीन के कीटों के विरुद्ध कुछ नीयोनिकोटीनोइड, ऑग्नेनोफोस्फेट और पाइरेथ्रोइड की जैव प्रभावकारीता
सलाहकार : डॉ० नीता गौड़

प्रस्तुत शोध नार्मन ई० बोरलॉग फसल अनुसंधान केन्द्र, गोविन्द बल्ल शि एवं प्रौद्योगिकी वि० विद्यालय पर खरीफ 2011 में किया गया। सोयाबीन एक महत्वपूर्ण फल कि 43 प्रति० त प्रोटीन औ० 20 प्रति० त तेल प्रदान करती है। इस पर 273 कीटों द्वारा किया जाता है जो फसल उत्पादन में बाधक है इसलिए सोयाबीन के प्रमुख कीटों पर नियंत्रण करना अति आवश्यक है।

वर्तमान प्रयोग में सोयाबीन के कीट नियंत्रण के लिए विभिन्न कीटनाशकों का किया गया। परिणाम बताते हैं कि अलीका 247 जेड सी @ 33 ग्राम ए०आई०/हैक्टेयर अलीका 247 जेड सी @ 27.5 ग्राम सम्पूर्ण पत्ती भेदक (तम्बाकू सूंड़ी, अर्द्ध कुण्डलक, बिहार रोएदार सूंड़ी) की जनसंख्या को प्रभावी ढंग से नियंत्रित करते हैं, इन्हीं कीटों के विरुद्ध थायमिथोक्जाम 25 प्रति० त डब्ल्यू० @ 25 ग्राम ए०आई० प्रति हैक्टेयर, लेम्बडासायहेलोथ्रीन 49 प्रति० @ 15 ग्राम ए०आई० प्रति हैक्टेयर, इथियान 50 प्रति० त ई० @ 750 ग्राम ए०आई० प्रति हैक्टेयर और इमिडाक्लोप्रिड 7.8 प्रति० त एस०एल० @ 20 ग्राम ए०आई० प्रति हैक्टेयर थोड़ी कम विशाक्तता दिखाते हैं, जबकि अलीका 247 जेड०सी० @ 33 ग्राम ए०आई० प्रति हैक्टेयर तना मक्खी के विरुद्ध सबसे ज्यादा विशाक्त था। अलीका 247 जेड @ 22 ग्राम ए०आई० प्रति हैक्टेयर अपनी कोक्सीनेला और मकड़ी के विरुद्ध कम विशाक्तता के कारण सुर लेकिन इमिडाक्लोप्रिड 17.8 प्रति० त एस०एल० @ 20 ग्राम ए०आई० प्रति हैक्टेयर प्रा तिक त्रुओं के विरुद्ध अत्यधिक विशाक्त था। अलीका 247 जेड @ 27.5 ग्राम ए०आई० प्रति हैक्टेयर से उपचारित भूखण्डों में अधिकतम उपज प्राप्त हुई, क्योंकि इन भूखण्डों में कीटों का पूर्णतः नियंत्रण किया गया था। इस प्रकार वर्तमान प्रयोग से पता चलता है कि अलीका 247 जेड०सी० @ 27.5 ग्राम ए०आई० प्रति हैक्टेयर का उपयोग सोयाबीन एकी त कीट प्रबन्धन में प्रभावकारी पाया गया है और प्रा तिक त्रुओं पर भी इसका हानिकारक प्रभाव नहीं देखा है।

नीता गौड़
(नीता गौड़)
सलाहकार

आकांक्षा
(आकांक्षा चन्द्र)
लेखिका